New Scientist

WEEKLY 27 July 2024

ZOMBIE GALAXY RETURNS TO LIFE AFTER 20 MILLION YEARS

'DARK OXYGEN' DISCOVERED IN THE DEEP OCEAN

HAVE WE FOUND THE UNIVERSE'S MISSING MATTER?

SPECIAL ISSUE

THE SMART GUIDE TO EXERCISE

What is the quickest way to get fit?

How much exercise is too much?

What is lost and gained by working out online?

The surprising benefits of slow running

When is the best time to exercise?

How much exercise do children need?

How fast do we lose fitness?

The best ways to boost your motivation

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New Scientist
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PLUS DID ABSTRACT MATHS EXIST BEFORE THE BIG BANG? MELTDOWN-PROOF NUCLEAR REACTOR BEES CAUGHT SLAPPING ANTS

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NS Live

Supermassive black holes that shine bright

Join astrophysicist Sophie Koudmani to dive into the science of supermassive black holes, the monsters that lie at the heart of almost every galaxy. We have recently discovered far more brightly shining black holes in the early universe than we can explain – so do we need to tweak our understanding of how the cosmos evolved? Hear Sophie at New Scientist Live in London's Excel Centre on 12 October or watch online.

newscientist.com/nslmag

Tour

The origins of modern medicine in France

Discover the foundations of the modern science of medicine in two French cities: Paris, where the "Paris School" of hygiene and hospital teaching flourished, and Montpellier, home to the world's oldest university medical faculty. This seven-day tour will run in July 2025. Head online for more details and to register your interest.

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Podcast

Culturelab

We hear from science journalist Zoë Schlanger about her new book *The Light Eaters*, which is all about the amazing abilities of plants. Schlanger walks us through some of these skills – from orchids sexually deceiving wasps to shape-shifting vines that flew under the radar of researchers for decades.

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DAVID STOCK

Seeds of hope Drones are helping to restore mangroves in the UAE

VICTOR1153/SHUTTERSTOCK

Other minds Which non-human animals are conscious?

Video

When drones plant mangroves

David Stock visited the United Arab Emirates to see how drones are being used to plant mangrove trees. The drones carry payloads of seeds and shoot them down into coastal mud where they can take root and flourish. The hope is that this project can inspire similar restoration initiatives around the world.

youtube.com/newscientist

Newsletter

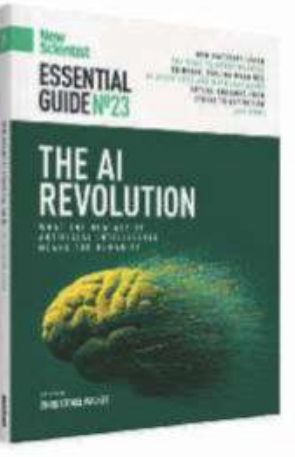
Wild wild life

In this edition, Penny Sarchet tackles the fraught topic of consciousness in animals. Though difficult to define, there is mounting evidence that a whole range of animals – from mammals and birds to even amphibians and insects – experience some form of consciousness.

newscientist.com/wild-wild-life

Newsletter

"Animals that pass the famous mirror test include some fish but not dogs"



Essential guide

Tools such as ChatGPT have put artificial intelligence on front pages around the world. So why has AI leapt forwards so suddenly? How can generative AI tools help you? And will this tech lead to human extinction? Get the lowdown on all this and more in our new *Essential Guide*, on sale now.

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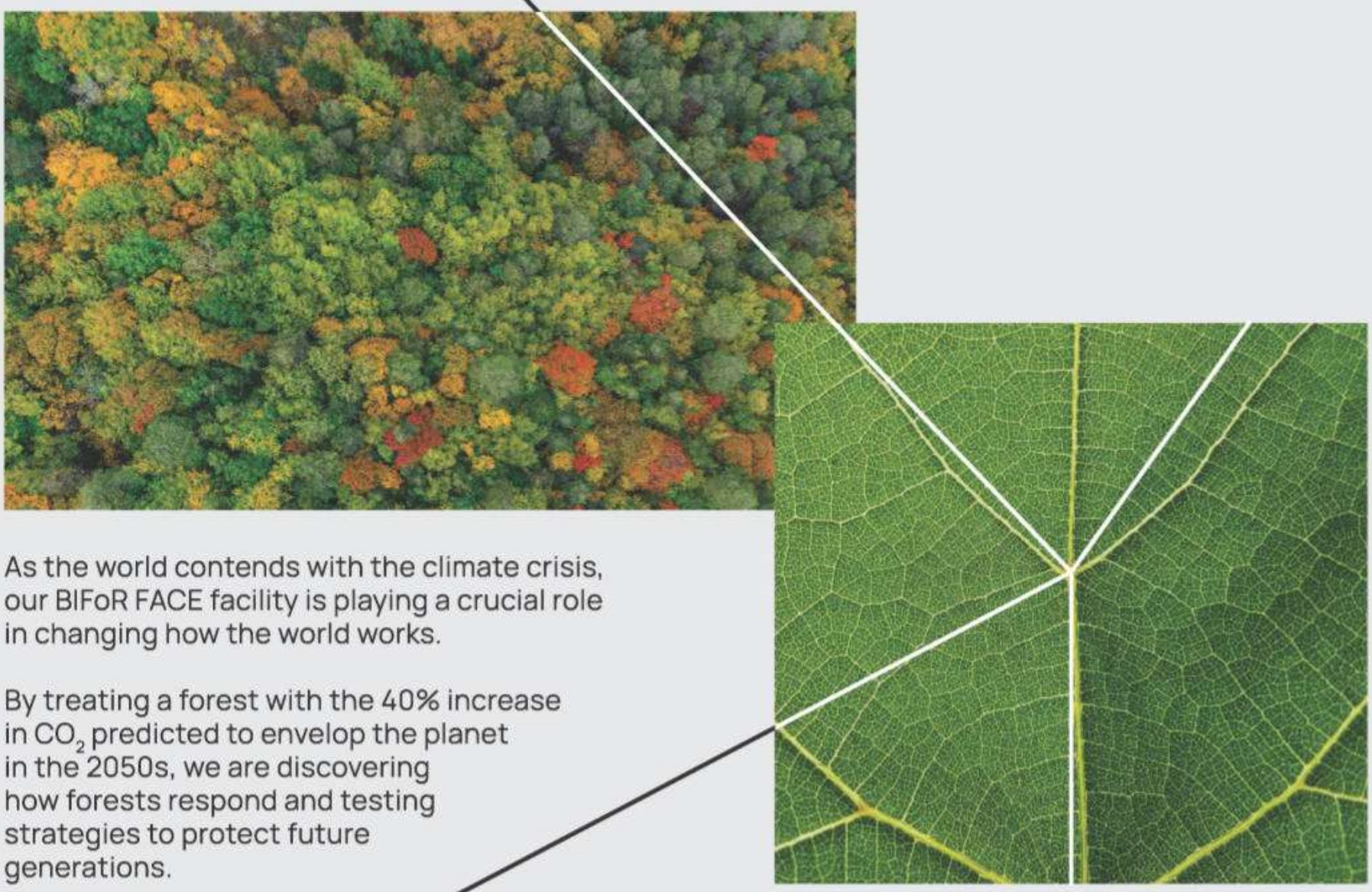
Revealing the effects of climate change on forests of the future



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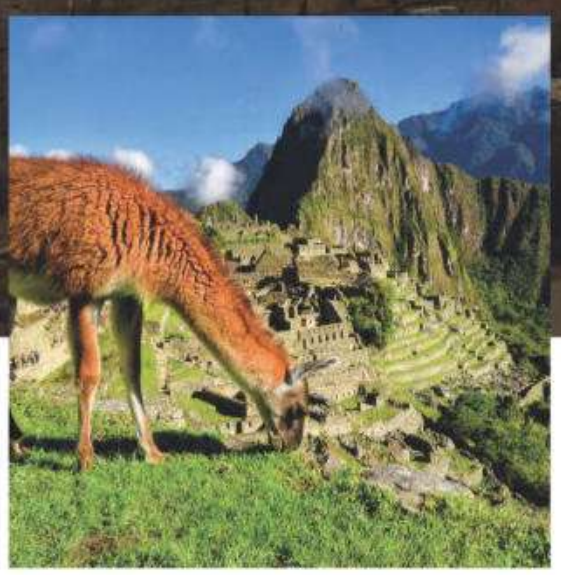

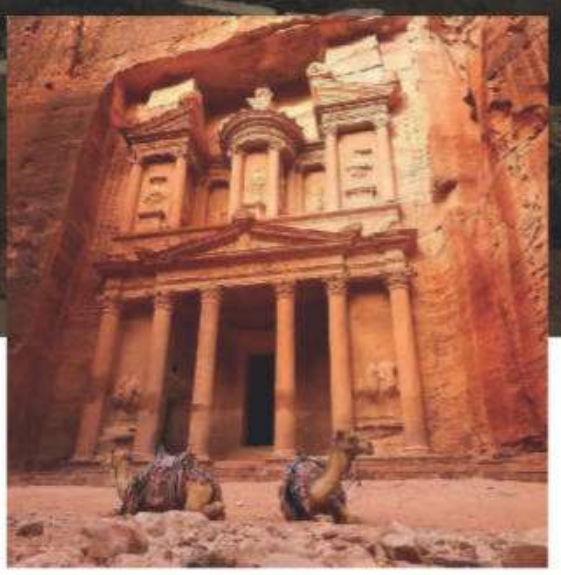

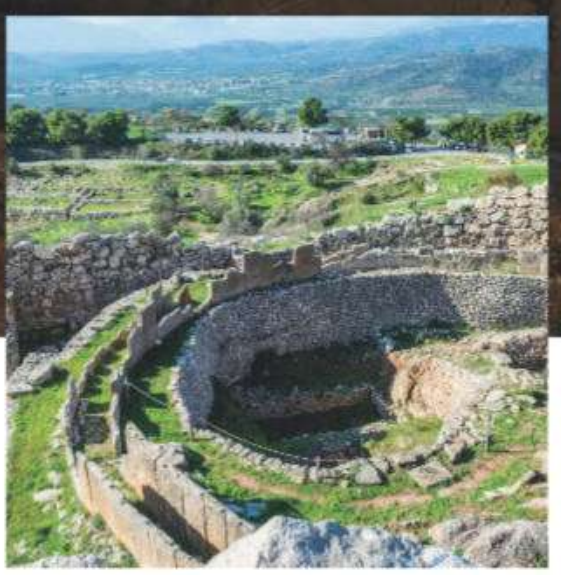

Machu Picchu and the science of the Inca: Peru

17 September 2024 | 10 days

Immerse yourself in the Inca civilisation's most important archaeological sites, including Machu Picchu as you discover the story of the Incas.

- Accompanied throughout by filmmaker and archaeo-anthropologist Peter Getzels.
- Visit multiple archaeologically important Inca sites and museums in Cusco and the Sacred Valley including Sacsayhuaman, Tambomachay, Tipon, Moray and the hidden gem that is Waqrapukara.
- Take part in an Inca cosmology and stargazing evening.
- Experience the local culture and cuisine.
- Enjoy guest lectures and walking seminars from professor of anthropology, Dr Jean-Jacques Decoste.

The archaeological wonders of Jordan

30 September 2024 | 8 days

Admire Jordan's many incredible historical marvels, from the ancient city of Petra, to the breathtaking canyons of Wadi Rum and the historic capital of Amman as well as stunning castles, caves, mosaics and excavations.

- A full day exploring the UNESCO World Heritage Site Petra.
- Travel the King's Highway between Amman and Petra.
- Jeep safari and Bedouin camp in the geologically fascinating Wadi Rum.
- Experience a traditional Bedouin evening with dinner and music, followed by stargazing in Wadi Rum.
- Relax in and explore archaeological remains around the Dead Sea.

Mycenae and Peloponnese archaeology: Greece

28 October 2024 | 8 days

A unique opportunity to explore Mycenae, one of the most important historical and archaeological sites in Greece. Visit many hidden gems and famous Mycenean sites of the Peloponnese.

- Experience a one-acre dig simulator and learn many of the techniques and specialist technology used at real dig sites.
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- Staying in the ancient coastal town of Nafplio and venturing out across this beautiful part of Greece.

Find out more at

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Make exercise fun again

Screen time isn't the only reason children are inactive – and there are easy solutions

AS WE prepare to settle down on our sofas to watch the latest generation of Olympians and Paralympians perform jaw-dropping feats of physical prowess, the irony won't be lost on many of us – especially if we are watching with children.

In May, the World Health Organization once again made it clear that the majority of adolescents globally don't get enough exercise, and children in England and Wales are among the most inactive in the world. As with many other issues, the finger of blame here is often pointed at screens. But the reality, as we explore in one part of our special issue on exercise (page 42), is more complex.

It is true that time spent in front of TVs, iPads and other devices competes with opportunities for physical activity. We also know that there are many benefits to spending time outdoors, in nature and connecting with others that children miss out on when glued to screens. But there are lots of other reasons why children are inactive – and in many cases, these are issues that can be easily remedied.

"The emphasis on competitive sports in schools strips the joy from physical activity for many"

Earlier this year, we reported that school uniforms may be contributing to the problem by being too restrictive, which could be addressed simply with a change in uniform policy. Meanwhile, the emphasis on competitive or elite sports in schools can strip the joy from physical activity, putting off many children.

This is especially true for girls, with disparities in physical activity by gender emerging at a very young age and widening dramatically when children enter senior school. The causes of this enjoyment gap include period problems and embarrassment about how they are performing in front of boys. Offering single-sex sports sessions and focusing more on activity and play, rather than competition, would go a long way to help.

So while events like the Olympics and Paralympics can be inspiring, we should shift the dialogue away from competitive sport and exercise in favour of activity, which is much easier to fit into daily life and can be fun and accessible for all. ▮

PUBLISHING & COMMERCIAL
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E. COTTRELL/SMITHSONIAN

Geology

An illuminating slice of history

It might look like modern art, but this slither of ancient rock is at least 2.5 billion years old. The sample, from the Gakkel Ridge deep in the Arctic Ocean, was photographed under a microscope using a special type of illumination known as cross-polarised light. The work helped reveal that the oxidation levels of a lot of Earth's mantle stayed stable across geologic time (*Nature*, DOI: 10.1038/s41586-024-07603-w).

Marine biology

‘Dark’ oxygen found in the deep

Sea-floor nodules full of valuable metals seem to raise oxygen levels in the ocean depths, suggesting they may have a valuable role in ecosystems, finds **Madeleine Cuff**

METALLIC nodules scattered across the seabed are a source of oxygen for nearby marine life – a finding that could upend our understanding of the deep ocean and affect plans to mine there.

Abyssal plains in some regions are scattered with potato-sized mineral lumps packed with cobalt, manganese and nickel, which are targets for industrial extraction.

Andrew Sweetman at the Scottish Association for Marine Science in Oban first noticed something strange about these areas in 2013, when he was doing research in the Clarion-Clipperton Zone, a nodule-rich part of the Pacific Ocean.

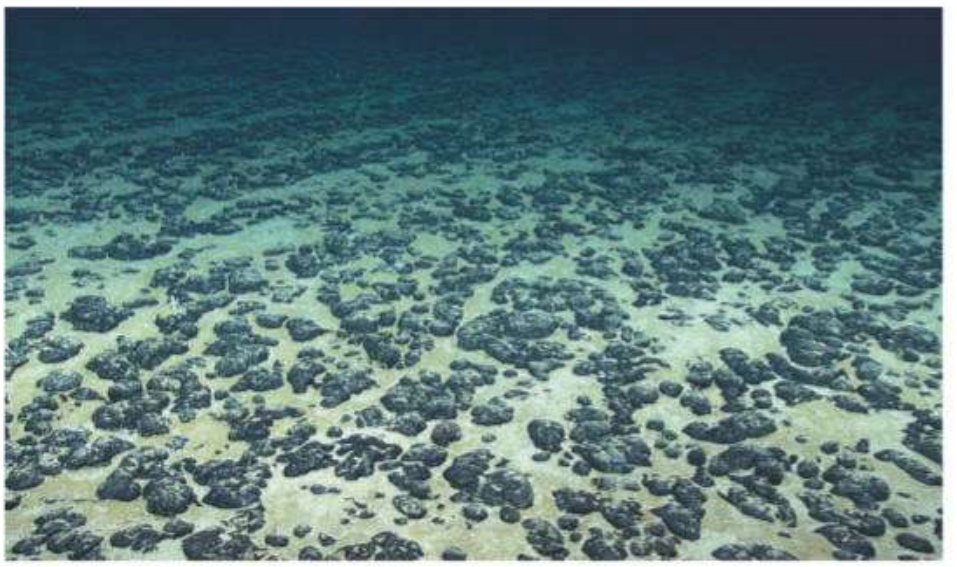
Sweetman and his colleagues were sending machines down to the ocean floor to seal off a patch of seabed and measure its oxygen flux. Instead of oxygen content decreasing in monitored sections, the data suggested it was rising.

Without any noticeable plant life, that didn’t make sense, says Sweetman. “I’ve been taught from a very young age that oxygenated ecosystems are only possible through photosynthesis,” he says. His conclusion was that the equipment was faulty. “I literally ignored the data,” he says.

Then, in 2021, Sweetman was on another research cruise in the Pacific and machines returned the same finding – increasing oxygen levels on the seabed. Using a different measurement approach yielded the same result.

“We were seeing the same oxygen production in these two different datasets,” says Sweetman. “Suddenly I realised that for the last eight or nine years I had been ignoring this hugely groundbreaking process.”

He and his colleagues deduced that the metallic nodules must be playing a role in raising oxygen levels in the deep sea after lab testing ruled out the presence of oxygen-producing microbes.



CLOCKWISE FROM TOP: NOAA; BLUE PLANET/ALAMY; C. BRIDGEWATER (2024)

Clockwise from top: manganese nodules on the sea floor off the south-eastern US; a sample from the Pacific being tested in a lab; oxygen generated by nodules may help organisms like cusk eels survive in deep water

Instead, Sweetman says the materials in the nodules are acting as a “geobattery”, generating an electric current that splits seawater into hydrogen and oxygen. “These nodules are being mined because there’s everything there that you need to make an electric car battery,” he says. “What if they are acting as natural geobatteries, by themselves?”

Each nodule can produce up to 1 volt of electric potential, the team found by probing them. If the rocks were clustered together, there would be enough voltage to split seawater into hydrogen and oxygen via electrolysis, explaining the elevated oxygen levels (*Nature Geoscience*, doi.org/m9b6).

“Potentially, we have discovered a new natural source of oxygen,” says Sweetman.

There are many outstanding questions. For example, the source of energy generating the electric current is still a mystery. It is also unclear under what conditions the reaction happens and the contribution this “dark” oxygen makes in sustaining surrounding ecosystems. “We don’t have all of the information yet, but we know it’s happening,” says Sweetman.

Emergence of life

In deep-sea environments devoid of sunlight and plants, some life forms get their energy from chemicals that erupt from the sea floor at hydrothermal vents. Some scientists think life on Earth first appeared at these vents, but early organisms would have needed a source of oxygen to make food from inorganic compounds. The findings raise the possibility that nodules were the source of oxygen to help life get started, says Sweetman.

That interpretation might be a stretch, says Donald Canfield at the University of Southern Denmark. Oxygen is needed to produce the manganese oxide in the nodules, he points out. “Oxygenic photosynthesis is a prerequisite for their production,” he says. “For this reason, oxygen production by the nodules does not represent an alternative type of oxygen production to be equated with oxygenic photosynthesis. It is very unlikely that they have played a role in the oxygenation of the planet.”

However, Ruth Blake at Yale University says the idea of oxygen production in the deep ocean is exciting and warrants research into its potential impact on deep-ocean ecosystems.

Sweetman’s study was part-funded by The Metals Company (TMC), a deep-sea mining firm that is looking to harvest metallic nodules in the Clarion Clipperton Zone. In response to the study, Patrick Downes at TMC said he has “serious reservations” about the findings, adding that TMC’s own analysis suggests Sweetman’s results are due to oxygen contamination. “We will be writing a rebuttal article,” Downes said in a statement to *New Scientist*.

However, the findings are likely to strengthen calls for a ban on deep-sea mining. Paul Dando at the UK’s Marine Biological Association says the paper reinforces the view of deep-sea scientists “that no mining should take place until we understand the ecology of these nodule fields”. ▮

Space

NASA's cancelled moon rover calls the 2026 crewed landing into question

Jonathan O'Callaghan

A FULLY constructed rover that was due to blast off to the moon next year will instead be dismantled due to budgetary issues, NASA has announced. This has led researchers to question whether the space agency is truly committed to landing a crewed spacecraft on the moon in 2026, as it currently claims.

The Volatiles Investigating Polar Exploration Rover (VIPER) was scheduled to be sent to the moon's south pole in September 2025 to hunt for water ice. Equipped with a drill, the rover would have looked for ice under the lunar surface in multiple locations, including in some permanently shadowed craters.

On 17 July, however, NASA announced that it was cancelling the mission. "Decisions like this are never easy," said Nicola Fox, associate administrator for NASA's Science Mission Directorate, in a statement. "But in this case, the projected remaining expenses for VIPER would have resulted in having to either cancel or disrupt many other missions. So we've made the decision to forgo this particular mission."

"The remaining expenses for VIPER would have meant cancelling or disrupting other missions"

NASA has already spent $450 million on the rover and the cancellation is expected to only save $84 million. The agency says it is open to "expressions of interest from US industry and international partners" to purchase VIPER, but if this doesn't happen by 1 August, it will be disassembled with a view to reusing its parts on future missions.

Phil Metzger at the University of Central Florida says the cancellation is a "very bad mistake" for NASA, especially in light of the agency's broader goal to land humans at the lunar south pole in 2026 as part of its Artemis programme. Plans to potentially use the moon's water ice as a resource for rocket fuel could also be under threat. "Having a rover with a drill is an absolutely vital part of the mission," says Metzger. "There definitely will be some effect on planning the human missions."

VIPER's cancellation also means that China may get a leg-up in the hunt for resources on the moon. Its upcoming uncrewed Chang'e 7 and Chang'e 8 missions, in 2026 and 2028 respectively, will target the lunar south pole to look for water ice.

Grant Tremblay at the Harvard & Smithsonian Center for Astrophysics says the cancellation highlights the budgetary issues facing NASA and other US government agencies, with NASA receiving 8.5 per cent less funding this year than it requested, at just short of $25 billion. "This is a perfect illustrative indication about how every single budget wedge at NASA is on fire," says Tremblay. "NASA cannot print money."

Other NASA projects, such as the Chandra X-ray Observatory and the Mars Sample Return mission to return rocks from the Red Planet, have also faced cuts or cancellations in the wake of dwindling budgets. "I have absolutely no doubt that more bad news is in the pipeline," says Tremblay. ▮

Environment

Green belts help cities keep their cool in summer

PRESERVING a "green belt" of countryside around urban areas helps cities stay cooler during the hottest times of the year.

We already know that many cities experience an urban heat island effect, because buildings and other human-made objects retain more heat than rural land. But as warm air rises in a city, it creates a layer of low pressure near the ground, which draws in cooler air from the surrounding countryside.

Shi-Jie Cao at the University of Surrey, UK, and his colleagues have now quantified this cooling effect by studying 20 years of satellite data up to 2020, across 30 Chinese cities. They found that having a city encircled by a band of countryside can reduce urban temperatures by up to 0.5°C, or 0.9°F (*Nature Cities*, doi.org/m9b3).

The cooling effect is most powerful when a rural band extends outwards for at least half of the city's diameter. Other effective actions to enhance cooling include joining up patches of green space, planting more woodland around cities and incorporating a few large lakes on a city's outskirts. "The number and adjacency of rural landscape patches emerge as pivotal factors," says Cao.

Although the team only looked at cities in China, the findings were robust when controlling for a city's local climate, meaning they should apply to urban areas found elsewhere, says Cao.

Graham Haughton at the University of Manchester, UK, says the work underscores the value of creating large areas of green or blue space, rather than small patchworks of rural land. The important consideration is the size and quality of the habitat. "Whether these are green belt or not is not of itself that important," he says.

CLARE JACKSON/ALAMY

Urban areas like Harrogate in the UK are often ringed by green spaces

The research could play into plans by the UK's new Labour government to reconsider rural construction. For decades, UK cities have been surrounded by protected green belts designed to stop settlements from endlessly expanding.

Now, in an effort to alleviate a nationwide housing shortage and accelerate economic growth, the UK government has said it will build 1.5 million homes in England over the next five years, allowing parts of the green belt to be built on.

David Rudlin at UK architecture firm Building Design Partnership says construction wouldn't affect green belt benefits if developers take only small chunks of land. ▮

Madeleine Cuff

Astrophysics

The galaxy gas leakage problem

The gas that surrounds galaxies appears to be more spread out than we thought. This could help solve a mystery over missing matter, discovers **Alex Wilkins**

SUPERMASSIVE black holes appear to be more powerful than our main cosmological model suggests, blasting the gas that surrounds galaxies much further away than expected. This finding could help explain several cosmological conundrums, including the fact that the universe seems to be missing large amounts of gas.

Most objects that we can measure in the universe, like stars and galaxies, emit light that we can observe from Earth. But measuring cold or spread-out gas, which is crucial for understanding how the universe works, is trickier because it often doesn't give off as much light.

A new method that astronomers have developed to map this gas makes use of the cosmic microwave background (CMB), which is the leftover light from the big bang. This light has been travelling through the universe for billions of years, and any object it has encountered along the way, such as galaxies and their gas, leaves a detectable imprint on it that can be measured.

"It's as if the galaxies are casting shadows on the CMB map," says Boryana Hadzhiyska at the University of California, Berkeley. But because these shadows are very faint, you need many millions of galaxies to get a clear signal, she says.

Gas spreading

Now, Hadzhiyska and her colleagues have measured these shadows in the highest detail yet and found that the gas causing them appears to be much more spread out than we find in our best simulations of the universe.

"It's finding something that we don't really expect, which is that the gas is way more extended than, for example, galaxy formation models predict," says Hadzhiyska.

To measure these shadows, she and her team combined one of the most detailed maps of the CMB, made using the Atacama Cosmology Telescope in Chile, with a vast catalogue of relatively nearby galaxies mapped out by the Dark Energy Spectroscopic Instrument in Arizona. By measuring how distorted the CMB map was in relation to the galaxies, they could find the average density of space, which told them where the galaxies' gas was distributed.

While typical simulations of the universe assume that the gas only extends 1 or 2 per cent outside a galaxy's outer limit, Hadzhiyska and her team found that it could stretch out as far as two to three times the galaxy's radius (arXiv, doi.org/m9b7).

This is probably due to phenomena associated with supermassive black holes, such as their jets being more powerful than we thought, though we don't know the exact mechanisms at play, says Hadzhiyska.

Supermassive black holes suck in gas and other matter, but also blow gas away

Biased cosmology?

This finding confirms earlier work that found hints of the spread-out gas using the same technique, says Leah Bigwood at the University of Cambridge, but the increased sensitivity boosts astronomers' confidence that it is real. "It's providing this evidence that maybe we're underestimating at the moment how much these supermassive black holes can push matter out, and if we are underestimating that, it can mean it would be biasing our cosmology."

One problem this could help solve is the so-called missing baryon problem. The CMB can be used to estimate how much baryonic matter – that is, ordinary rather than dark matter – there is in today's universe. But the amount of matter we can observe with light-based telescopes is much less than predicted.

This missing matter might just be gas spread out beyond where we can see it, says team member Simone Ferraro, also at the University of California, Berkeley. "None of the gas has disappeared, it's just been pushed out way beyond where people could see before. Now we have these new techniques, and this new data, we're able to see that far out."

It could also help to resolve a disagreement between two ways of measuring how clumpy the universe is. The first method uses the CMB and the standard model of cosmology to work out how spread out the universe is now, which gives a higher result than another technique measuring how much the gravity of galaxies bends light.

"Maybe we're underestimating how much supermassive black holes can push matter out"

But if the CMB calculation is rerun using the new gas distribution data, then the tension between the measurements appears to go away, says Hadzhiyska. However, a more detailed analysis will be needed to prove it, she says. ▮

MARK GARLICK/SCIENCE PHOTO LIBRARY/ALAMY

Physics

Jiggling robot reveals the perfect way to untangle threads

Karmela Padavic-Callaghan

PHYSICISTS may have found a fix for the rage-inducing tangles that crop up in everything from electronics cords to necklaces: to free a single thread, you must shake it not too fast and not too slow, but with just the right frequency.

Ishant Tiwari at the Georgia Institute of Technology in Atlanta and his colleagues created a vibrating robot to determine how to best jiggle a single thread from such a tangle. They gathered cotton fibres into balls by rolling them around in a box. This ensured that all the tangles they tested would be similar. The tangles were each attached to a piston on a robot by a single thread.

Tiwari and his colleagues set the robot to jerk up and down at various frequencies and vibrate the tangle, which revealed that there is a sweet spot for the perfect untangling frequency.

When the shaking frequency was low – just a few shakes each second, or a few hertz – the thread that was attached to the piston moved together with the tangle and it stayed stuck. At the high end, greater than about 37 shakes per second, the tangle also remained jumbled. The energy of the shaking was diverted into damped oscillations across the whole tangle, so it tugged less on the specific thread the researchers were trying to release from the ball.

But at about 17 shakes per second, the tangle jumped and jerked more chaotically, and each twitch contributed a small pull on the thread. When the effect of these pulls accumulated, the thread came loose from the tangle (*Physical Review E*, doi.org/m87x).

The researchers have presented results on only one type of thread so far, but their work may help unravel a more general property of the fibre tangles that pervade our daily lives, and how to deal with them. ▮

Health

Covid-19's toll in India was worse for women than men

Grace Wade

YAWAR NAZIR/GETTY IMAGES

New Delhi, India, in March 2020, under a covid-19 curfew

THE coronavirus pandemic may have affected India more than previously estimated, with the most severe life expectancy declines among women, younger demographics and certain social groups.

Previous mortality estimates in India relied on official death records. Lockdowns disrupted this system, which already underreported deaths in women and children before the pandemic. It doesn't collect information like ethnicity or caste either, says Sangita Vyas at Hunter College in New York.

So Vyas and her colleagues gathered information on deaths in India from the country-wide National Family Health Survey. It asks participants whether anyone in their household died in the past four years and, if so, to provide data like the person's date of death, age and gender.

The researchers analysed data from more than 765,000 people who completed the survey in 2021. They found that there were about 17 per cent more deaths in 2020 than in 2019. If similar increases occurred across the country, that indicates almost 1.2 million excess deaths in 2020 – eight times the official number of covid-19 deaths in India in 2020 (*Science Advances*, doi.org/m9b8).

Between 2019 and 2020, overall life expectancy at birth declined by more than 2.5 years in the sample, compared with a 1.5-year decline in the US during the same period. These changes differed by gender, age and social group, too.

17%

The increase in deaths in India from 2019 to 2020

For instance, it fell about three years in women compared with just over two years in men. This contrasts with global trends, which reveal men had greater increases in mortality than women during the covid-19 pandemic. Prior research shows Indian households spend less on healthcare for women relative to men, so covid-19 may have amplified these pre-existing disparities, says Ridhi Kashyap at the University of Oxford. Strict lockdowns also hindered access to healthcare, potentially increasing maternal mortality rates, she says.

Unlike in other countries, life expectancy declines seen in this study were largely driven by deaths in younger people. Increases in mortality among women and girls under 20 years old contributed roughly the same amount as deaths in women between ages 60 and 79. "We think that those increases in mortality are coming from indirect effects of the lockdown in India," says Vyas. The effects could include disrupted access to childhood vaccines and treatments for tuberculosis, a leading cause of death in India.

There were also stark differences between social groups. High-caste Hindus experienced a 1.3-year decline in life expectancy, while those who were Muslim or belonged to a lower caste saw 5.4-year and 2.7-year declines, respectively.

Public health experts have long been aware of India's health inequities. Yet these findings highlight their magnitude, says Vyas, and studying them "is important for developing policy responses".

However, the study has limitations. Due to disruptions during lockdown, the survey respondents only came from 14 of India's 36 states and union territories, and the sample was demographically representative of about one-fourth of India's population. Also, it didn't look into cause of death. "We can only speculate on why these patterns may be," says Kashyap. ▮

Science of music

How music tempo changes as a star ages

Michael Le Page

KEVIN MAZUR/GETTY IMAGES

Dolly Parton performing in Los Angeles, California, in 2022

THE tempo of songs released by many popular musicians increases until the star reaches their early 30s, then steadily declines, falling below the teenage level when they hit their 50s.

"We saw this very clear downward trend," says Geoff Luck at the University of Jyväskylä in Finland. "We are confident that tempo really does decline over the lifespan."

The number of beats per minute, or the tempo, is a key property of music that can be used to convey different emotions, says Luck. "So if that is changing across an artist's lifespan, it means the effect their music will have on fans will necessarily change as they age," he says. "It might partially explain why younger fans don't connect so well with older artists."

Luck and Alessandro Ansani, also at the University of Jyväskylä, started with a data set of 1.2 million songs on Spotify that included the company's analysis of each track's tempo. The pair then excluded artists whose careers spanned less than 20 years, who had released fewer than three albums, who were born before 1955 or whose birth date was unknown.

The researchers also tried to exclude songs that might skew the analysis, including live performances, Christmas songs, classical music, soundtracks and remixes. That left nearly 15,000 songs from 207 artists, including Pearl Jam, Kylie Minogue, Cyndi Lauper, Barbra Streisand, Dolly Parton, Kenny G, Tech N9ne, Judas Priest and Juan Gabriel.

They then used an AI system to assess how the age of these musicians was linked to the tempo of the music they released. With bands, the researchers only looked at the lead singer's age.

According to their results, the tempos of songs by these musicians averaged about 120 beats per minute when the musician was in their teens, rising to almost 123 bpm in their early 30s. It then fell by nearly 2 bpm per decade (bioRxiv, doi.org/m9b2).

In a study of just 10 popular artists, Luck also examined how the tempos of these individuals changed over time. The clearest declines were in songs by Michael Jackson, Elvis Presley and Whitney Houston. Madonna and Elton John had the greatest variation in tempos over time. In Madonna's case, this may reflect her work with different collaborators and styles, says Luck. ▮

Life

Sea slugs work together to hunt prey in packs

Jake Buehler

A PACK of slugs may not sound like fearsome predators, but then you aren't a sea anemone. The finding that sea slugs can work collectively in this way shows that predatory collaboration isn't limited to more complex carnivores like wolves and lions.

Ghostly white and adorned with a mane of horn-like spurs, *Berghia stephanieae* is a nudibranch sea slug native to the Atlantic Ocean and Mediterranean Sea that feeds only on brown sea anemones (*Exaiptasia diaphana*). Kate Otter and her colleagues at the University of Massachusetts Amherst noticed these finicky fellows tended to feed in groups of several slugs.

To determine if this was deliberate pack hunting or just random chance, the researchers conducted feeding experiments. When they placed sea slugs in a tank with two anemones, the slugs didn't divide up into equally sized squads to attack both quarries, as you would expect if the groupings were totally random. Even in a tank with a 1:1 ratio of slugs and anemones, where each predator could have had its own prey, the slugs preferred to team up against particular anemones (bioRxiv, doi.org/m88d).

This behaviour suggests the slugs were working together. In addition, the groupings didn't match the predictions of a mathematical model that assumed the slugs were all attacking independently. The hunting groups were often small – usually around three slugs, but sometimes numbering six or more – but they were larger than expected by chance.

"[The study is] a nice demonstration that the same forms of cooperative behaviour have evolved as a way of solving the challenges of life in vastly different organisms and ecological circumstances," says Michael Cant at the University of Exeter, UK.

This cooperation may help slugs subdue their dangerous prey. Brown sea anemones are armed with venomous tentacles on all sides, but they flop them in one direction when attacked, says Otter. For the sea slugs, ambushing their quarry from multiple angles thus "helps reduce the injury load on the individual", she says.

In additional experiments, the predators didn't seem to follow other slugs' slime trails to their prey, nor did they treat a single slug attacking a nearby anemone like a dinner bell. The slugs also don't seem to prefer injured anemones. So for now, it isn't clear how the sea slug teams are coordinating or choosing their targets.

Talia Borofsky at Princeton University is interested in the questions the research raises, such as whether this behaviour also happens in the wild. ▮

Sea slugs attack their brown anemone prey as a team

KATE OTTER

Space

There is a new formula for defining a planet – but Pluto is still out of the club

Jonathan O'Callaghan

A MATHEMATICAL formula to determine whether objects in space should be classed as planets could make it easier to identify bodies around other stars – but it is bad news if you want Pluto to regain its planethood.

In 2006, the International Astronomical Union (IAU) demoted Pluto from planet to dwarf planet status in a controversial decision that left our solar system with eight planets. The IAU cited the fact that Pluto hadn't cleared its orbit of other debris as a critical factor in determining what counts as a planet, a decision that irked many astronomers and the public alike.

Jean-Luc Margot at the University of California, Los Angeles, and his colleagues now propose an easier way to define a planet. They say a planet is any body that orbits a star or the remains of a star, and has a mass larger than 1/200th that of Jupiter but smaller than 13 times the mass of Jupiter.

The lower limit, which is equal to 10^{23} kilograms, corresponds to a midpoint between the mass of

"The current definition is quite restrictive. We're proposing a simpler, mass-based system"

current dwarf planets and planets of our solar system, but could be adjusted slightly, says Margot. The upper limit is the point at which deuterium fusion begins, moving into the realm of stars rather than planets.

"The current IAU definition is quite restrictive," says Margot. "We're proposing a simpler, mass-based system."

Margot's new system would leave our solar system with its eight clearly defined planets, Pluto not included, and also applies to all known 5700 exoplanets orbiting other stars. "All of them satisfy this criterion by a large margin," says Margot. "So that's sort of satisfying."

One objection to the IAU's planet definition is that it is difficult to see if a body has cleared its orbit. To address this, Margot and his colleagues investigated whether a planet can "dynamically dominate" its orbit, meaning it has the potential to do so.

The team used a mathematical formula linked to the planet's mass and distance from its star that produced a clear divide between the planets of our solar system and smaller bodies, such as the dwarf planets Pluto, Eris and Ceres. Importantly, there is no need to actually observe objects in a planet's vicinity to make the distinction, says Margot, which is impossible to do for exoplanets with our current technology.

The definition also doesn't require any direct measure of a planet's roundness, known as hydrostatic equilibrium, which is a requirement of the IAU definition. "Objects that are dynamically dominant typically will be round," says Margot, and such objects will always be larger than 10^{23} kilograms (*The Planetary Science Journal*, doi.org/m8zg).

Mike Brown at the California Institute of Technology, who was instrumental in Pluto's demotion with the discovery of Eris in 2003, says the work is a "fun way" to define a planet that will spark more debate.

Margot will present the work at an IAU meeting in Cape Town, South Africa, in August. ▮

Technology

Robot dog uses flamethrower to suppress weeds

A ROBOT sporting a flamethrower could stop weeds growing on farms, potentially offering a replacement for harmful herbicides.

Even highly targeted herbicides can cause environmental problems, affecting local wildlife, and "superweeds" are evolving resistance to the most common weedkillers like glyphosate.

Now, Dezhen Song at Texas A&M University and his colleagues have developed a weed control system that uses a burst of heat from a propane-powered flamethrower controlled by a robotic arm, attached to a Spot robot manufactured by Boston Dynamics.

DEZHEN SONG ET AL. (2024)

A Spot robot equipped with a flamethrower for tackling weeds

Rather than incinerate a weed, the robot is designed to identify and heat up the centre of the plant, which can stop it growing for several weeks, says Song. "The weeds don't die – you just suppress their growth so it gives your crop a chance to fight the weed."

Song and his team first tested the flame nozzle to make sure they could accurately target the weed's centre. Then they deployed the robot in a cotton field planted with weeds native to Texas, like common sunflower (*Helianthus annuus*) and giant ragweed (*Ambrosia trifida*). In five trials, the robot located and torched the weeds, with an average of 95 per cent of the flame focused on the weed (arXiv, doi.org/m879).

One limitation is the battery life of Spot, which can only run for about 40 minutes before it needs charging, says Song, but the researchers are working on using a longer-lasting robot. They are also looking at equipping the robot dog with a device that can deliver more than 10,000 volts, which will stop weed growth for longer, he says.

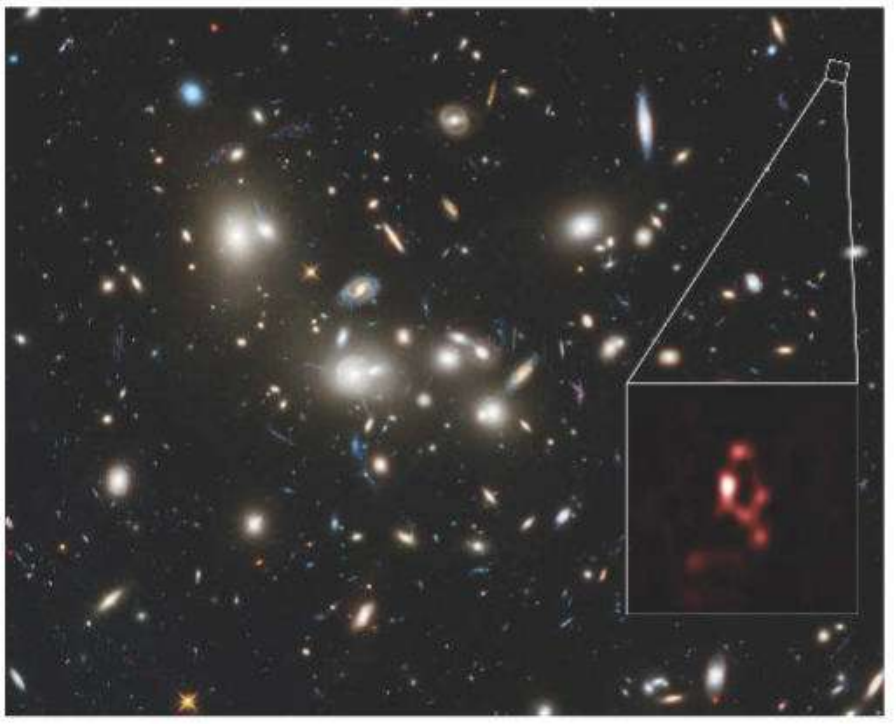
The robot is more precise than other weed-burning methods and its success will depend on how well it can avoid damaging crops, says Simon Pearson at the University of Lincoln, UK. ▮

Alex Wilkins

Astronomy

Zombie galaxy pops back into life 20 million years after it died

Leah Crane



ALMA/NASA, ESA, ESO AND D. COE (STSCI)/J. MERTEN (HEIDELBERG/BOLOGNA)

A galaxy cluster that contains the undead galaxy (inset)

A STRANGE, zombie-like galaxy has been spotted in the distant universe. It stopped forming stars for 20 million years before coming back to life in a burst of activity, and it could help explain a mystery about the earliest galaxies.

"We've seen galaxies going through bursts of star formation, and we've also seen galaxies that are no longer forming stars, but this is the first instance of seeing a galaxy that's stopped forming stars and then gone through this sort of rejuvenation process," says Guido Roberts-Borsani at the University of Geneva in Switzerland.

Roberts-Borsani and his colleagues observed the galaxy, called A2744-YD4, using the James Webb Space Telescope (JWST). Because of the time the light took to travel to the telescope, they saw the galaxy as it was just 650 million years after the big bang, making it one of the earliest galaxies to form.

They found signatures of bright, young stars as well as dimmer, older ones, which has never been seen before in one galaxy (arXiv, doi.org/m8zp). The stars' ages imply that after 100 million years of forming stars, the galaxy went quiet for around 20 million years. Then it started churning out stars again.

This behaviour could be explained by mergers with other galaxies, which can provide fresh fuel for star formation to a dead galaxy, or it could be due to gas getting blown away by supernovae and then falling back into the galaxy. The process has never been seen before, so figuring out what caused it may be crucial for our understanding of the most distant galaxies.

"This is the first instance of seeing a galaxy that's gone through this sort of rejuvenation process"

"Young stars can easily outshine old ones, so in order to accurately infer the masses of galaxies, we need to know whether there could be an older population that is outshone by bright young stars," says Claude-André Faucher-Giguère at Northwestern University in Illinois. "Neglecting this possibility can introduce major errors in our census of the galaxy population – with fundamental implications for theoretical models."

The main such errors would be in our calculations of these galaxies' masses and ages. When the glare from the young stars hides the old ones, the galaxies look younger and less massive than they are.

When JWST began taking pictures of the early universe, it found many galaxies that were bigger and older than expected. This led some researchers to suspect that our previous idea of early galaxies forming stars steadily might be wrong. Bursts and lulls in their activity could explain the new observations.

"There have not been any smoking-gun observations for the kind of bursty star formation that would be needed [to explain the JWST findings], but this is such evidence," says Christopher Hayward at the Flatiron Institute in New York.

This is only one galaxy, so whether or not this behaviour is common remains to be seen. If it is, it could prove to be a major paradigm shift in how we view the early universe. "We expect that in the first few hundred million years of the universe, basically all galaxies should be undergoing this very bursty, violent mode of star formation," says Hayward. "But we'll of course need much larger samples to prove that this is a ubiquitous phenomenon." ▮

Health

Retinol's anti-ageing effects may alter your skin microbes

Larissa Fedunik

THE ingredient retinol, which is common in anti-ageing skincare products, may work through its effect on the skin microbiome.

When applied topically, retinol gets converted into a nutrient called retinoic acid. Lab studies suggest that retinoic acid prevents water loss and degradation of the protein collagen, which may reduce the physical signs of ageing.

To learn more about how this happens, Xiao Liu at Tsinghua University in China and his colleagues – including researchers at the skincare company HBN – recruited nine Chinese women aged between 22 and 38 years old. The women were asked to use a lotion developed by HBN containing 0.15 per cent retinol each evening for 28 days, while avoiding using other kinds of leave-on skincare during the trial period.

The researchers collected skin swabs on the first day and every week later. They then extracted DNA from the swabs, which they sequenced to map the women's skin microbiomes.

After the first week, the women had reduced levels of the bacteria *Stenotrophomonas maltophilia* and *Pseudomonas* species, which can cause skin and soft tissue infections. Testing the moisture content of the women's skin throughout the trial also supports the idea that such lotions improve skin hydration, which has been linked to greater elasticity and reduced wrinkle depth (bioRxiv, doi.org/m8x5).

"There is a significant need in the research community to understand what skin microbiota are doing, which this study has addressed by assessing skin metabolites," says Holly Wilkinson at the University of Hull in the UK. She says that the study should be extended to include older people and those of different ethnicities to assess retinol's effects more broadly. ▮

Technology

A meltdown-proof nuclear reactor

First ever full-scale demonstration of a reactor that can cool itself in an emergency is a success

Alex Wilkins

A LARGE-scale nuclear power station in China is the first in the world to be impervious to dangerous meltdowns, even during a full loss of external power. The design can't be adapted to existing nuclear reactors, but could be a blueprint for future ones.

All modern nuclear power plants rely on powered cooling mechanisms to take excess heat away from reactors or, in the event of an emergency, human intervention to shut the plant down. Water or liquid carbon dioxide are often used as coolants, but these typically rely on external power supplies to function.

If these systems fail, then the reactors can become too hot and this can lead to explosions, with the plant literally melting from the excess heat. This was one factor in the Fukushima nuclear accident in Japan in 2011, where a loss of standard and emergency power systems led to a meltdown.

CHINA HUANENG GROUP

The High-Temperature Gas-Cooled Reactor Pebble-Bed Module (HTR-PM) in Shandong, China

A relatively new kind of reactor design, called a pebble-bed reactor (PBR), has the advantage of being passively safe, which means that if power for cooling systems is lost, then the reactor can safely shut down by itself. Rather than use highly energy-dense fuel rods like many other reactor designs, PBRs use a large number of low-energy-density "pebbles" as fuel, which contain a small amount of uranium surrounded by graphite. This can help slow the nuclear reaction and withstand high temperatures.

This lower energy density means any excess heat will be spread out over all of the pebbles, and so it will be easier to transport away using natural cooling processes like conduction and convection, says Zhe Dong at Tsinghua University in China.

Small, working prototype reactors have been built in Germany and China, but now Dong and his colleagues have demonstrated that the system works with a full-scale nuclear plant, the High-Temperature Gas-Cooled Reactor Pebble-Bed Module (HTR-PM) in Shandong.

To test the plant, which became commercially operational in December 2023, Dong and his team switched off both of HTR-PM's modules as they were operating at full power, then measured and tracked the temperature of different parts of the plant afterwards. They found that HTR-PM naturally cooled and reached a stable temperature within 35 hours after the power was removed (*Joule*, doi.org/m87r).

Because the emergency cooling system doesn't depend on any complicated technology, it is very safe, says Mamdouh El-Shanawany, formerly at the International Atomic Energy Agency.

Other countries may want to look into adapting this technology for their own future reactors, after more extensive measurements have been taken of the plant as it cools down, says El-Shanawany. ▮

Zoology

Chimps gesture at a pace similar to human conversation

CHIMPANZEES trade gestures with rapid speed when socialising, similar to the rate at which humans engage in a conversation.

Gal Badihi at the University of St Andrews, UK, and her colleagues made the discovery by analysing five wild chimpanzee (*Pan troglodytes*) communities in East Africa, examining 8559 gestures made by 252 chimps. They recorded face-to-face interactions between apes, noting the timing between gestures and responses.

Their analysis of the ape "conversations" revealed that the time between chimp signals was remarkably similar to human exchanges – even a bit faster. "On average, there are 120 milliseconds between the end of one gesture and the start of the next one," says Badihi. "In humans, the average is around 200 milliseconds, so it's really close timing."

Although all the chimp communities used quick responses, the timing varied between groups. For instance, the Sonso community of chimps in Uganda took a few milliseconds longer to return a gesture than the other chimpanzee communities in the study (*Current Biology*, doi.org/m88f).

Timing differences like these also exist in human languages. People who speak Japanese, for example, generally have a quicker turn-taking conversation style than those who speak Danish. "We don't know exactly why," says Badihi. "As with humans, we don't know if it's a cultural difference, something we learn over time or a response to the environment."

CATHERINE HOBAITER

Chimpanzees grooming and playing in the Budongo Forest in Uganda

Only 14 per cent of the chimp interactions the team observed included some exchange. Most involved a single gesture, such as "get away" or "come with me", to which the other participant would respond by fleeing or following. But when the chimps were negotiating for food or grooming, back-and-forths were more common.

"It shows us that communication is a cooperative and socially engaging process in animals outside of humans," says Badihi. "It could be that the processes involved in human language actually evolved much earlier than we thought." ▮

Corryn Wetzel

Space

A closer look at Titan's strange seas

The hydrocarbon lakes and rivers of Saturn's moon have similarities with our own water world

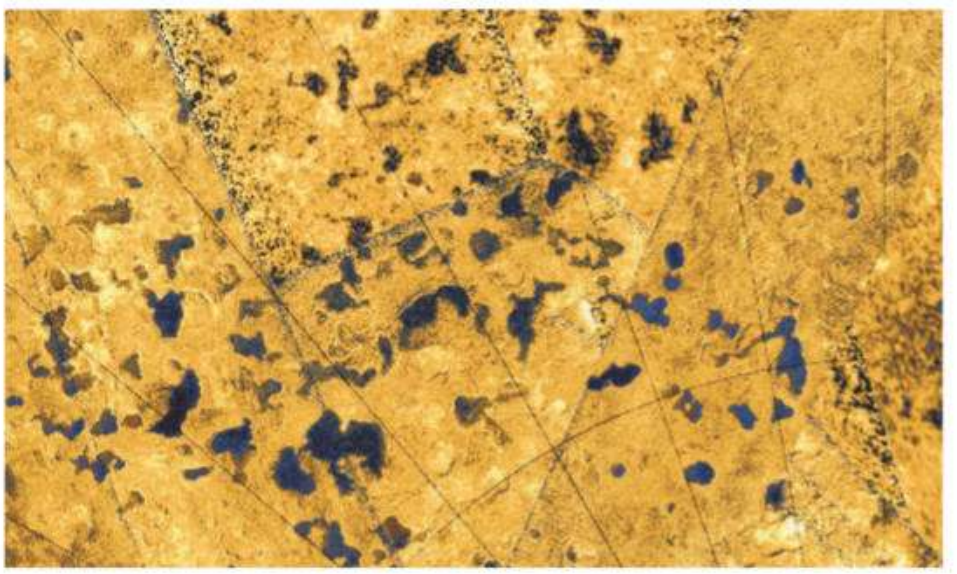
Alex Wilkins

OUR most detailed look yet at the strange lakes of Saturn's moon Titan has revealed a diverse seascape, similar to Earth's combination of freshwater rivers and salty oceans.

Unlike Earth's water oceans, Titan's lakes consist of methane and ethane, which are liquid at the planet's average surface temperatures of about -179°C (-290°F).

Radar measurements from NASA's Cassini spacecraft, which orbited Saturn between 2004 and 2017, have hinted at differences in the lakes' properties, such as their composition and the waves on their surface. But there wasn't enough information in the signals to distinguish between them.

Now, Valerio Poggiali at Cornell University, New York, and his colleagues have mapped the composition and surface of Titan's seas using a different radar technique, revealing an increasing amount of ethane as you travel down the planet from its north pole. "The more north you go, the cleaner and purer the seas are; they're more methane-dominated," says Poggiali.



NASA/ESA

Lakes of methane and ethane on the surface of Titan, imaged by radar

Previous radar measurements were made using signals emitted and received at the same location, on the Cassini probe. This meant that the reflected radio waves were polarised, or twisted, in one direction.

The new study analysed signals from Cassini's radar that had been reflected off the surface of the lakes and then received using radio antennae on Earth operated by NASA, called the Deep Space Network. The shallower angle of the reflected signal meant that it included two kinds of polarised waves, giving Poggiali and his colleagues more information about the lakes' properties (*Nature Communications*, doi.org/m8q6).

They found that many of the rivers and estuaries that fed the lakes and seas had rough surfaces, probably caused by wind-whipped waves. This might be a sign of active tides or currents feeding into the lakes, says Poggiali.

"Activity on the surface of the seas is super important if you want to plan a future mission, like a Titan submarine, but also to be able to better understand Titan's environments in terms of wind and its atmospheric characteristics."

"Activity on the surface of the seas is super important if you want to plan a Titan submarine mission"

Poggiali and his colleagues also found that the rivers had a higher composition of methane before they fed the lakes. This could help us track the methane and ethane cycle on Titan, says Ingo Mueller-Wodarg at Imperial College London.

"When a river enters a large, salty ocean on Earth, then you would see that, near where the river enters, you have a lower salinity of the water," he says. "It's kind of a similar thing happening here, only that it's not about the content of salt, but the relative proportion of methane and ethane." ▮

Animals

Bees use their wings to slap ants that try to raid their nests

WHEN ants threaten their hive, Japanese honeybees see off the enemies with the flick of a wing.

Ants often invade honeybee nests, seeking to steal honey, prey on eggs or kill worker bees. In defence, bees have been known to fan their wings to blow ants away. Now, researchers have documented them making contact with their wings and physically batting ants out of the hive, a behaviour that hasn't been studied before.

Footage from a high-speed camera shows that guard bees, positioned near a nest's entrance, tilt their bodies towards approaching ants and flutter their wings while pivoting away. A successful hit sends the ant flying.

Many beekeepers seem unaware of this strategy, says Yoshiko Sakamoto at the National Institute for Environmental Studies in Tsukuba, Japan. "I myself did not notice this behaviour during my approximately 10 years of beekeeping experience," she says.

Sakamoto and her colleagues introduced three local species of ant to the entrance of two Japanese honeybee (*Apis cerana japonica*) colonies and filmed hundreds of showdowns between the insects (*Ecology*, doi.org/m8q7).

SEIJI NARITA

A Japanese honeybee slapping an ant with its wing

In most of these interactions, the bees smacked at ants with their wings. For two ant species, about one-third to half of attempts flung ants away. Wing-slapping was far less successful against Japanese wood ants (*Formica japonica*), a larger and faster species.

Ants vary in their level of menace to bees: some species bite or kill workers, while others are less of a threat. Bees may have evolved to favour the fanning defence to avoid making contact with the more dangerous ants, but wing-slapping may be a more efficient option against other species, the researchers suggest. ▮

Carolyn Wilke

Chemistry

How to keep drugs safe outside a fridge for weeks

Karmela Padavic-Callaghan

MANY medications must be refrigerated or they lose their effectiveness, but now a method of packing them into a stiff gel could make them last longer at room temperature.

Drugs can break down if not stored properly, which can make them unsafe. High temperatures, for example, can break the chemical bonds that maintain the shape of a drug molecule, disrupting its function. For some drugs, shaking can make the molecules clump together, reducing their efficacy.

Matthew Gibson at the University of Manchester in the UK and his colleagues developed a method that could make handling protein-based drugs more practical. They mixed proteins with hydrogel ingredients to create a stiff white structure that can be loaded into a syringe. In this form, proteins that would usually have to be chilled to -20°C (-4°F) withstood temperatures up to 50°C (122°F) and kept functioning under those conditions for up to four weeks (*Nature*, doi.org/m8qq).

The hydrogel gets its stiffness from small molecules linked into large chains, which break under force. In a syringe, the chains are broken by pushing down on the plunger, turning the mixture into a liquid. The hydrogel remnants are too big to enter the syringe's needle, so only the drug leaves the syringe.

The researchers tested this method with several compounds, including bovine insulin. They also sent some of the mixture through the mail and found that the proteins withstood the temperatures and jostling of the postage system.

Alex Brogan at King's College London says this method would most benefit countries and regions where cold storage is rare and prohibitively expensive. If it works with protein-based vaccines, it could make disease prevention more equitable. ▮

Analysis Artificial intelligence

Super AI is still sci-fi

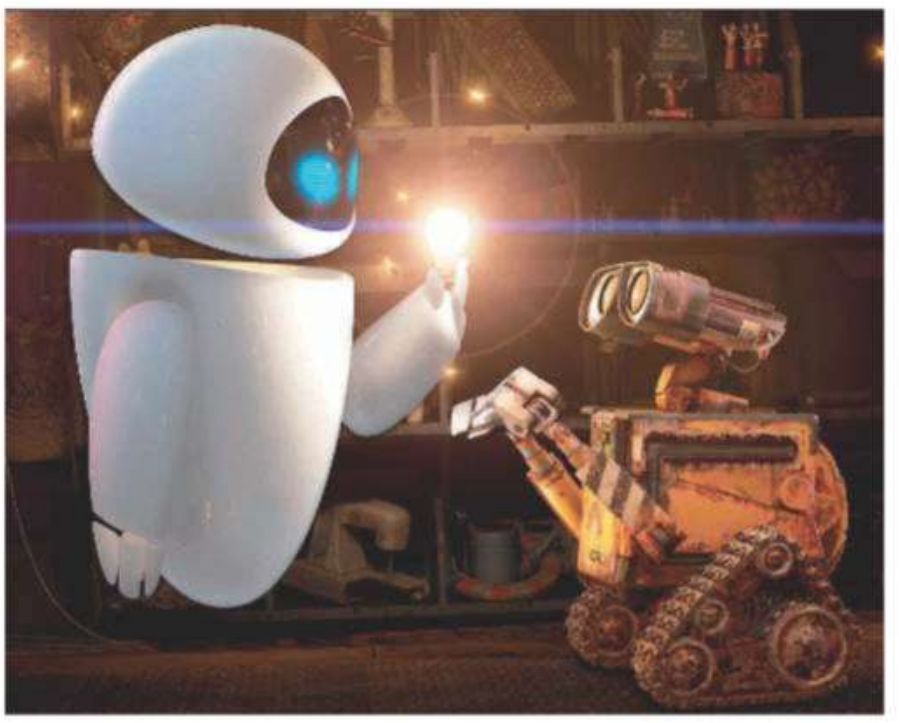
Hype surrounding the latest AI models has many people convinced that they are sentient – and that's a problem, says **Chris Stokel-Walker**

AROUND one in five people in the US believe that artificial intelligence is already sentient, while around 30 per cent think that artificial general intelligences (AGIs) capable of performing any task a human can are already in existence. Both beliefs are false, suggesting that the general public has a shaky grasp of the current state of AI – but does it matter?

Jacy Reese Anthis at the Sentience Institute in New York and his colleagues asked a nationally representative sample of 3500 people in the US their perceptions of AI and its sentience. The surveys, carried out in three waves between 2021 and 2023, asked questions like "Do you think any robots/AIs that currently exist are sentient?" and whether it could ever be possible for that technology to reach sentience.

"We wanted to collect data early to understand how public opinion might shape the future trajectory of AI technologies," says Anthis.

AI models aren't as sophisticated as the personalities in *Wall-E*



TCD/PROD.DB/ALAMY

The findings of the survey were surprising, he says. In 2021, around 18 per cent of respondents said they thought AI or robot systems already in existence were sentient – a number that increased to 20 per cent in 2023, when there were two survey waves. One in 10 people asked in 2023 thought ChatGPT, which launched at the end of 2022, was sentient (arxiv, doi.org/m8qp).

Optimism bias

"I think we perceive mind very readily in computers," says Anthis. "We see them as social actors." He also says that some of the belief in AI sentience is down to big tech companies selling their products as imbued with more abilities than the underlying technology may suggest they have. "There's a lot of hype in this space," he says. "As companies have started building their brands around things like AGI, they have a real incentive to talk about how powerful their systems are."

"There's a lot of research showing that when somebody has a financial interest in something happening, they are more likely to think it will happen," says Carissa Véliz at the University of Oxford. "It's not even that they might be misleading the public or lying. It's simply that optimism bias is a common problem for humans."

Journalists should also take some of the blame, says Kate Devlin at King's College London. "This isn't helped by the kind of media coverage we saw around large language models, with overexcited and panicked reports about existential threats from superintelligence."

Anthis worries that the incorrect belief that AI has a mind, encouraged by the anthropomorphising of AI systems by their makers and the media, is shaping our perception of their abilities. There is a risk that if people believe AI is sentient, they will put more faith than they ought to in its judgements – a concern when AI is being considered for use in government and policing.

One way to avoid this trap is to recast our thinking, says Anthis. "I think people have hyperfocused on the term 'artificial intelligence'," he says, pointing out it was little more than a good branding exercise when the term was first coined in the 1950s. People are often impressed at how AI models perform on human IQ tests or standardised exams. "But those are very often the wrong way of thinking of these models," he says – because the AIs are simply regurgitating answers found in their vast training data, rather than actually "knowing" anything. ▮

10%

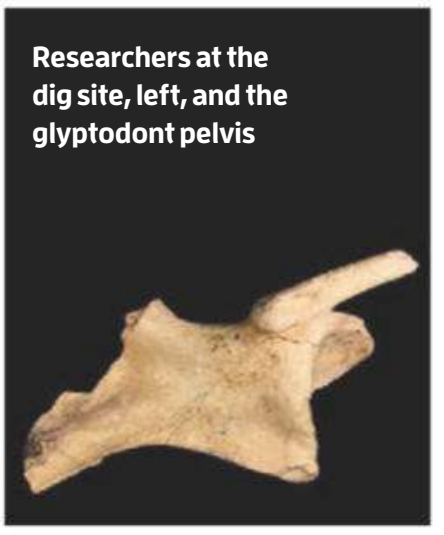
Proportion of people in the US that believe ChatGPT is sentient

Archaeology

Butchered bones hint at earlier human arrival in South America

Christa Lesté-Lasserre

DEL PAPA ET AL., 2024



Researchers at the dig site, left, and the glyptodont pelvis

MARKS discovered on the 21,000-year-old bones of a giant, armadillo-like animal in Argentina may be the oldest evidence of humans in southern South America.

If confirmed by further research, the findings could push back the date humans were known to be living in the area by about five millennia, to the end of the last glacial period. That would predate the currently accepted arrival of humans on either American continent by at least 1000 years, says Nicolas Rascovan at the Pasteur Institute in Paris, France.

"Humans could have been present in South America much earlier than we thought and even earlier than what is assumed of the entry of people in North America," he says.

Scientists generally believe that people migrated across the Bering Strait from Asia into North America between 15,000 and 20,000 years ago and then spread down into Central and South America. But the proposed dates have stirred significant controversy among experts ever since the mid-19th century.

Recently, the discoveries of apparently butchered bones in Mexico from up to 26,000 years ago and jewellery made of giant sloth bones in Brazil from up to 27,000 years ago have made researchers question whether humans reached the Americas much earlier.

Further south, in the "cone" that includes southern Chile and Argentina, the oldest butchered bones generally date to about 16,000 years ago.

But new discoveries from a construction site along the Reconquista river in greater Buenos Aires appear to support the idea that humans appeared there earlier. Surveyors found multiple hip and tail bones and shell parts of what was once a 1.5-metre-long mammal called a glyptodont, which resembled an armadillo, in this case from the genus *Neosclerocalyptus*.

21,000

Estimated age in years of bones with apparent stone tool marks

Its bones and shells were marked by 32 straight cuts that looked like they had been made by stone tools, given the inner stripes within the grooves and their V-shaped form. Radiocarbon dating placed the specimen in the last glacial maximum, as late as 21,000 years ago.

Rascovan and his colleagues scanned a selection of cut marks and analysed 3D models of them. The angles of the entry point of the grooves and the depth of the cuts reflect a pattern that is consistent with butchering of fresh bone, they say.

The bones showed no signs of scraping from the teeth of carnivores or scavengers. The team's investigation of the sediment around the bones and shell suggests that the animal parts were buried quickly in partially wet climate conditions like those found in the region 21,000 years ago (*PLoS One*, doi.org/m8p2).

The findings are "an extraordinary claim" given the currently accepted archaeological evidence about human presence in South America, says Ben Potter at the University of Alaska Fairbanks. But the study lacks critical data like detailed maps of the site and sediment layers, he says. "There remains room for ambiguity."

Team member Miguel Delgado at the National University of La Plata in Argentina says the team feels confident about the findings since the marks strongly fit with scientific models of cuts made by human tools. ▮

Technology

Tiny solar-powered drones could stay aloft indefinitely

Matthew Sparkes

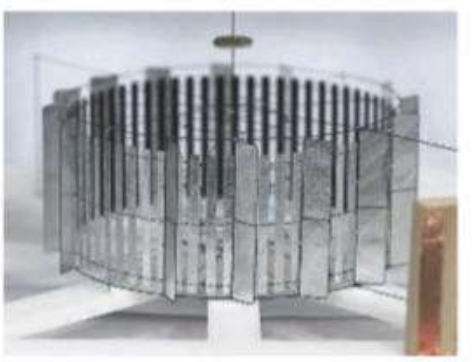
A DRONE weighing just 4 grams is the smallest solar-powered aerial vehicle to fly yet. Although the hummingbird-sized prototype only operated for an hour, its makers say their approach could result in insect-sized drones that can stay in the air indefinitely.

Making solar-powered drones smaller is challenging because small solar panels can't produce as much power, says Mingjing Qi at Beihang University in China. Electric motors also get less efficient as more energy is lost to heat, he says. To avoid this diminishing cycle, Qi and his team developed a simple circuit that scales up the voltage produced by solar panels from 4.5 volts to between 6000 and 9000 volts.

Rather than using an electromagnetic motor like those in electric cars and quadcopters, they used an electrostatic propulsion system. This works by attracting and repelling components with alternating electrical charges arranged in a ring to spin a single rotor blade like a helicopter. The lightweight components are made with wafer-thin slivers of carbon fibre covered in delicate aluminium foil (*Nature*, doi.org/m8qr).

"We have managed to get a micro-aerial vehicle to fly using natural sunlight for the first time. Before this, only very large, ultralight aircraft could achieve this," says Qi. ▮

This prototype miniature drone is powered by a ring of solar panels



WEI SHEN/JINZHE PENG/MINGJING QI

Environment

Storm forecasts get up to speed

Hurricane models are improving, but there are still big misses when storms rapidly intensify

James Dinneen

BEFORE slamming into islands in Grenada earlier this month, Hurricane Beryl strengthened from a tropical cyclone to a major hurricane in less than a day. The storm – the strongest on record in the Atlantic so early in the season – killed several people and caused widespread damage in the Caribbean, Latin America and the US Gulf Coast.

But Beryl's effects might have been worse were it not for new forecasts able to better predict such "rapid intensification" events. "[The forecast] was indicating this thing was really going to go," says Mark DeMaria at the US National Oceanic and Atmospheric Administration (NOAA).

Rapid intensification events – defined as an increase in wind speed of about 55 kilometres per hour or more within a span of 24 hours – can make hurricanes more dangerous by leaving people with little time to prepare, and are becoming more likely due to climate change. But they are notoriously tricky to forecast.

"We conceptually understand what contributes to rapid intensification," says Brian Tang at the University at Albany in New York. "Predicting and forecasting rapid intensification is a completely different question."

As recently as 2015, forecasts of rapid intensification were completely unreliable, and improvements are still far from perfect. But this year, NOAA is using new models that could be the most reliable yet. One – called SDCON-RII – outperformed all others when tested on the past five Atlantic hurricane seasons. This stems from higher resolution modelling, more accurate physics and incorporating more data from aircraft, satellites and other sensors to ensure models start with the correct initial conditions.

Of Hurricane Beryl's nine separate rapid intensification events, NOAA accurately predicted four of them at least 24 hours in advance, whereas past forecasts might have predicted just one, says DeMaria. But the forecast has limitations: it didn't accurately predict the storm's peak intensity and didn't capture more than half the events. "There's still potential for big misses," he says.

Subtle factors such as eddies at the surface of the ocean or thunderstorms around the eye of the storm can set off rapid intensification. Tang says these are difficult to measure and the physics behind their influence on storms isn't fully understood.

Where physics falters, statistics can help. But forecasts of rapid intensification based on statistical or AI models have been hindered by a lack of data on these relatively rare events, says Karthik Balaguru at Pacific Northwest National Laboratory in Washington state.

Thanks to boosts in computing power and data collection, forecasts have steadily advanced, with reliability increasing by around 20 to 25 per cent between 2015 and 2020. And as ocean temperatures rise with climate change, forecasters may have more to work with. "There have been a lot more hurricanes," says DeMaria. "The dataset is bigger." ▮

NASA EARTH OBSERVATORY

Hurricane Beryl over Mexico's Yucatán peninsula on 5 July

Technology

Do you share your smartphone PIN with your partner?

MORE than half of people surveyed think that sharing smartphone login details is a common and healthy part of relationships, although only slightly more than half actually hand over their PIN.

Periwinkle Doerfler at New York University and her colleagues investigated public habits and perceptions of sharing smartphone access with partners, and they found that there was no strong consensus on whether privacy or transparency was the best strategy.

The researchers surveyed 531 people from around the world, 378 of whom had partners. They found that 51 per cent of those in relationships gave their phone PIN to their partner, and vice versa.

To learn more about people's perceptions of how others use their phones, the team combined their data with a 2019 survey conducted for software firm Norton of 2050 people in the US. Of respondents in the combined survey, 59 per cent thought people commonly shared their phone PIN with their partner, while 57 per cent saw the practice as healthy. Sharing biometric log-ins, such as registering your partner's fingerprint on your phone, was seen as common by 39 per cent of people and as healthy by 49 per cent.

More intrusive practices were still considered to be widespread, even though people had less positive attitudes towards them. Monitoring your partner's search history or text messages, for example, was seen as common by 43 and 46 per cent of people respectively, but these were also seen as toxic habits by 85 and 87 per cent of respondents.

"Monitoring your partner's search history or text messages was commonly seen as toxic"

Among the most negatively viewed behaviours was tracking a partner's location, with 74 per cent of people believing it to be a toxic practice even with a partner's consent and 95 per cent saying it is toxic if doing it without consent. But some people thought tracking was still routinely done: 25 per cent thought it was common with consent and 14 per cent without (arXiv, doi.org/m8w7). ▮

Matthew Sparkes

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Sustainable ruminant farming: Beyond the burp

The climate impact of methane released by cows and other ruminants is well-known, but how big is the problem, and how are researchers and farmers making ruminant farming more sustainable?

Although methane is a potent climate gas, the vast majority of global warming is caused by burning fossil fuels like coal and oil releasing carbon dioxide into the atmosphere. Focusing solely on cows misses the bigger picture in the long term.

"Methane emitted from agriculture (soils and ruminants), is about 30% of total methane," says Michael Lee of Harper Adams University.

"We need to reduce global methane emissions by about 30%. Hence there is this eye on agriculture because it is easier to pinpoint every single cow and target those rather than methane released from mines and natural gas leaks." he added.

Sustainable ruminant farms can actually benefit the environment. For example, grasslands managed by these farms store significant amounts of carbon in the soil and manure from cows can be a valuable fertiliser, reducing reliance on manufactured options.

Not all beef is created equal – sustainable farming practices can significantly reduce the environmental impact of raising cows, critically lowering methane emissions.

"The global average for beef production is around about 50kg of carbon dioxide equivalent (CO_2e) per kilogram," says Lee. "At Harper Adams we can produce it at 5kg CO_2e/kg" This is achieved by selective breeding, dietary changes, and gut supplements.

"It's not the cow, it's the how. The bad guys are not the farmers" says Lee. He believes ruminant farmers are part of the solution to reduce the impact on the environment. "They're custodians of land. They can use that land to capture carbon and ensure that nitrogen/phosphorus is recycled. We need to support them, to deliver that, not demonize them."

You can find out more by visiting the Future of Food and Agriculture stand at New Scientist Live 2024. For more details go to: live.newscientist.com

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Culture columnist
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Comment

Consider the ant

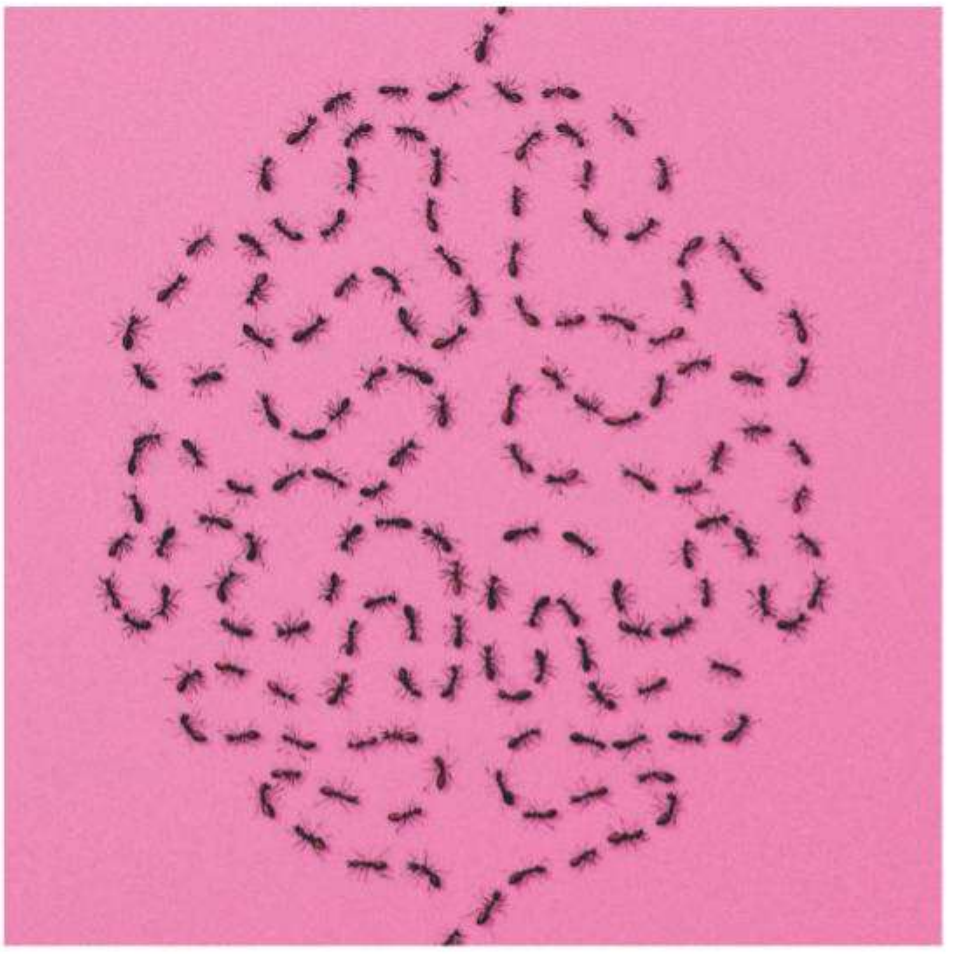
Insects such as ants are being overlooked in favour of the darlings of conservation. We need to celebrate their brilliance, says **Robert Barrie**

WHEN a humpback whale arrived in the seas off Mexico last year, the scientific world sat up in wonder. And with good reason, because the whale – aptly named Frodo – had just finished an 11,000-kilometre journey that began in the Mariana Islands, in the north-western Pacific.

Whales and birds are frequently touted as Earth's chief navigators. Insects, too, are showcased – often represented by butterflies and bees. Ants, however, are rarely on the lips of those discussing nature's best pilots. As someone who has researched ant navigation, this is disheartening, particularly when considering the lack of action to address ants' dwindling numbers compared with that for other insects and mammals.

Like whales, ants display extraordinary spatial skills as part of their remarkable navigational toolkit. Their most well-known strategy – chemical signalling via pheromones to guide nestmates along shared paths – barely scratches the surface.

Recent research I was involved with shows a new navigational characteristic for ants living in complex environments. Wood ants (*Formica rufa*) returning to the nest through the cluttered undergrowth exhibit idiosyncratic routes. That is, whereas one ant might always go to the right of a bush and then under a log when returning home, another might always go to the left and then over. This suggests the ants are relying on visual cues as opposed to pheromones, the responses to which would show considerable overlap. It is the visual memories of the ant's first return to the nest that form the basis for the journeys to come.



ADRIÀ VOLTÀ

Or take the North African desert-residing ant *Cataglyphis fortis*. In another ploy of navigational notability, each ant uses an internal "step counter" and celestial cues to calculate its position relative to the nest in the barren Saharan terrain. A recent study revealed that this species also constructs mounds as visual cues to help find the way home.

How rising global temperatures will affect ants living in such harsh environments remains to be seen. But overall, insects are already in dire straits. A 2020 study found that terrestrial insect numbers are decreasing by 0.92 per cent per year on average – that's a lot of insects considering there are around 10 quintillion currently estimated to be alive. The UK State of Nature report for 2023 estimates that numbers of crop pest predators – which includes ants – have fallen by 34 per cent in the UK since 1970.

Ants don't benefit from a wide range of conservation strategies. Humpback whales, on the other hand, have thankfully seen their numbers bounce back due to protection initiatives. Indeed, a study of UK conservation policies found that mammals receive more uniform protection than insects. Lepidoptera – butterflies and moths – dominate insect policies, which, the work suggests, is to the detriment of other insect groups such as hymenopterans, of which ants are members.

Despite how vital insects are to our planet, their biodiversity is in jeopardy, and it is our duty to make a case for invertebrate protection across the board. Their kaleidoscope of individualistic behaviour, such as remarkable navigational accuracy, originating from relatively basic neural circuits, is key to attracting public support. If only more people knew that dung beetles navigate using the Milky Way, for example, their presence on conservation lists would surely be more frequent.

Yes, Frodo travelled 11,000 kilometres. But large whales have upwards of 10 billion neurons. A wood ant has just a fraction of that – far less than a million – yet she can still travel the same route home across a dense woodland. A route unique to her and none other. Perhaps thinking of insects as individual animals, rather than their collective species, is a start.

Robert Barrie is a journalist and researcher of neuroethology

Field notes from space-time

Cosmic query

The answers to a reader's questions about the nature of black holes start off with a shift in perspective, says **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an associate professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her most recent book is *The Disordered Cosmos: A journey into dark matter, spacetime, and dreams deferred*

Chanda's week

What I'm reading
The plot of Octavia Butler's Parable of the Sower *starts in July 2024, so, like many others, I am reading it.*

What I'm watching
For better or for worse, a lot of the Dutch soap opera Goede Tijden, Slechte Tijden.

What I'm working on
Developing a research programme for a grant proposal.

This column appears monthly. Up next week: Graham Lawton

IN A recent column, I wrote about black holes. A curious reader sent in a letter asking some interesting follow-up questions about topics that I didn't really have time to delve into, more specifically about the relationship between matter and a black hole, as well as what happens at the centre of it all.

The easy answer to the second part is that we have no idea. End of column! More seriously, part of what makes black holes such interesting phenomena to study is that perspective really matters. We know that they are demarcated by a boundary known as the event horizon. Outside of it, we can calculate trajectories for photons (particles of light) and massive matter like spaceships where they escape the black hole's gravity. By contrast, inside the event horizon, all trajectories lean towards the centre of the black hole. There is no escaping. Even light, which travels at the fastest speed in the cosmos, can't go fast enough to get out. In the simplest scenario, this is actually what defines the event horizon: it is the location in space-time where escape velocity is the speed of light.

From the perspective of someone or something that crosses the event horizon, there is no sign saying "No Return Beyond This Point". Space-time continues like normal. But the gravitational forces at work here are so intense that, in practice, it is unlikely a person would be intact by the time they reached the event horizon.

The perspective of someone watching an object cross the event horizon is completely different. The reason why has to do with the way gravity affects the passing of time. Time moves more slowly in a strong gravitational field than in a weak one. As a result, time passes faster on Mount Kilimanjaro than it does in New York, since New York is closer to the majority of Earth's mass. The primary gravitational force any clock experiences on Earth is from the matter that makes up our beautiful home planet. This effect is called gravitational time dilation.

Now imagine how much this effect is amped up by a black hole, which will typically be much more massive than Earth: an observer at a safe distance will measure time such that an object near the black hole is moving very slowly. In fact, it will look like the object never actually crosses the event horizon, since the closer it gets, the stronger the gravitational time dilation.

"A black hole can evaporate, although unfortunately on a timescale longer than the age of the universe"

In other words, what happens at the edge of a black hole is a matter of perspective. The other thing to keep in mind is that a black hole behaves like it is a massive object, but it isn't necessarily made of matter in the same sense that, say, a baby is. The simplest black hole solution to the equation that governs gravity in Albert Einstein's general relativity is actually what we call a vacuum solution. That is, there is no matter present. Just a black hole acting like matter.

In practice, the black holes that we observe astrophysically tend to have a lot of matter around them. But this isn't a property unique to black holes. Many massive objects tend to accrete – that is, attract – more matter into their orbit. The sun, for example, has a solar system that probably formed from an accretion disc around it. Earth has a satellite, the moon, that pulls our planet and causes its oceans to have tides.

What's more, a black hole doesn't need to have matter around it to be a black hole. The properties of space-time that define a black hole can exist in that state with no matter present. There is something of a caveat to this, however. Einstein's relativity doesn't take quantum mechanics into account. Fifty years ago, Stephen Hawking showed that when quantum features are taken into account, black holes radiate particles. Given enough time, a black hole can even evaporate because of this. Unfortunately for the experimentally curious, that timescale for any observable black hole is longer than the age of the universe, so it is unlikely we will ever witness it.

This might make you think that there is no point to researching quantum black holes, because we can't see their effects. But special relativity came about as a theory because Einstein used a series of thought experiments that turned out to be quite insightful. Similarly, research about the quantum nature of black hole event horizons may provide insight into what happens at the centre of a black hole.

You may recall that the black hole equations as we understand them suggest there is a singularity there. What this really means is our equations break down. Applying quantum theory to black holes and studying associated quantum gravity ideas might help us figure out how to make a functional mathematical description of singularities. Understanding the black hole event horizon may give us insight into the black hole singularity in the middle, and whether we can ever see it or not, this would be pretty exciting to know! ▮

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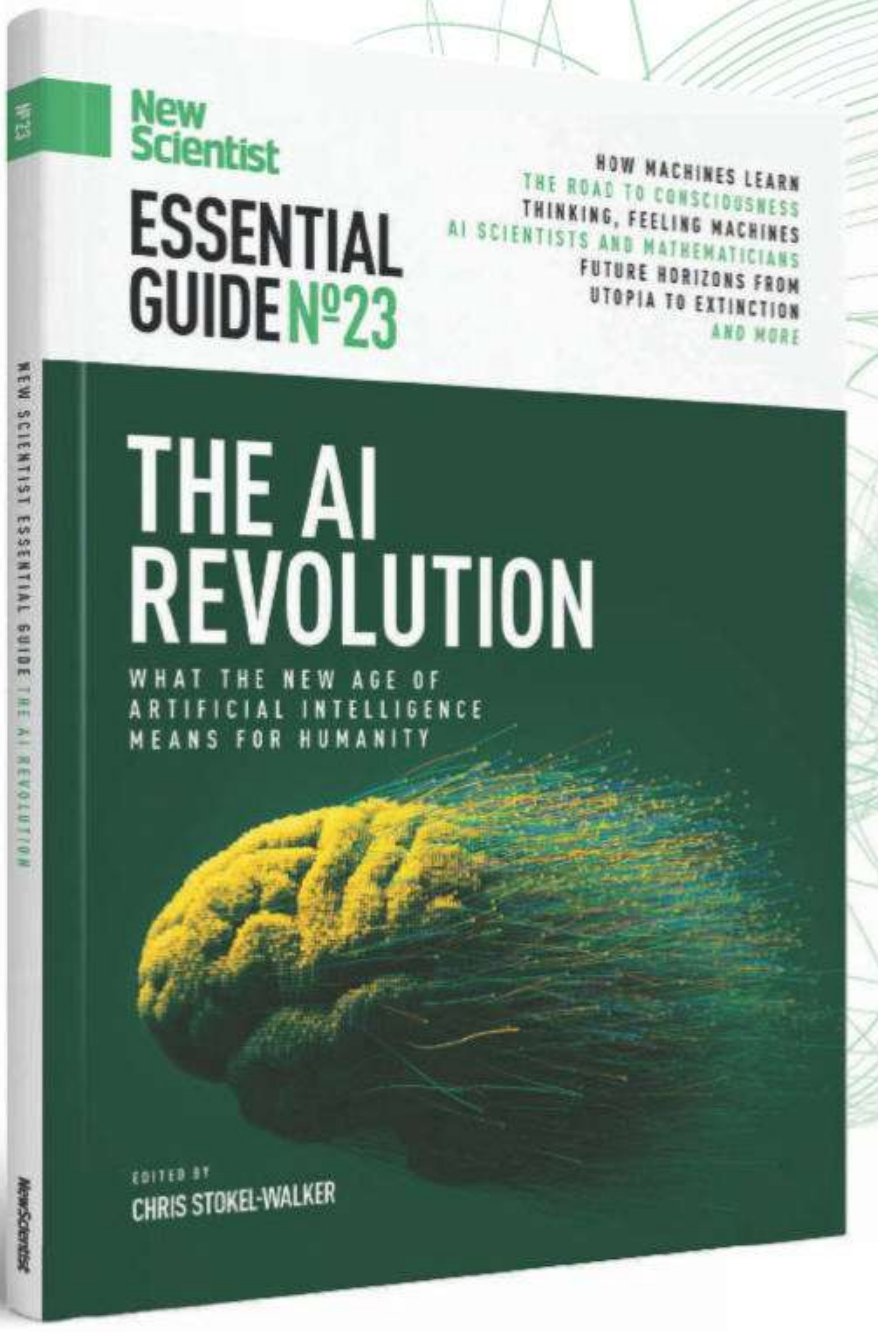

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DNA/DESIGN AND ARCHITECTURE

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VIRGINIA KILBORN

Hole in the wall

Publisher **Eden Project**

THIS epic image (far left) shows an inventive reincarnation of an abandoned Chinese quarry as an open-air library. Enclosed bookshelves line the stone, and concrete stairs have been installed to connect the different levels and stone platforms where people can practise calligraphy or sit and read.

"Quarry 8" is one of nine chosen as tourist destinations by local government from thousands of disused quarries in Jinyun county, China. Workers here mined for tuff, a rock formed from volcanic ash, for over 1300 years until 2000.

This is just one example of what derelict mines can become, featured in the book *102 Things to Do With a Hole in the Ground* by Peter Whitbread-Abrutat and Robert Lowe. As the world adopts green energy, many mines are expected to close, says Whitbread-Abrutat. "But there are lots of weird, wonderful and surprising ways to reuse these sites."

Moving clockwise, this photo shows the dazzling aluminium frame of an Audi A8 – a revolution in lightweight car design – suspended in the Red Dot Design Museum in Essen, Germany. It is part of the world's largest exhibition of contemporary design, which contains about 2000 objects selected via the museum's design awards. The rust-coloured contortions of steel that support the building are remnants of the Zollverein coal mining complex.

The image below this shows deep excavations in Australia, now home to the Stawell Underground Physics Laboratory, which hunts for dark matter. The lab is more than a kilometre below the remote gold mining town of Stawell, Victoria.

102 Things to Do With a Hole in the Ground is available to buy via the Eden Project online shop.

Chen Ly

Editor's pick

We can't let the solar boom use up agricultural land

6 July, p 10

From Richard Emmett, Blacksburg, Virginia, US

You report that the boom in solar energy around the world has led to panels being installed on prime agricultural land. This is bad news, and there are many more sensible alternatives: most obviously barren desert land that can't grow food.

Another option would be the roofs of buildings, such as homes and barns built to face the sun – this is very common in Germany. Best of all would be building on covered car parks, so that cars can be slowly charged directly during the day when the sun is shining. Indeed, France is requiring this for new car parks over a certain size. Sacrificing prime agricultural land should be the last resort.

Will AI ever get to appreciate a film?

29 June, p 9

From Robert Rawlinson, Bristol, UK

Moheb Costandi writes that artificial intelligence can analyse the neuronal activity of movie watchers and identify which scenes they were observing. While this shows we can map commonality in brain activity for AIs to tap into, we lack the ability to capture the phenomenological quality of the "experience". For AIs to cross the divide into consciousness, we would need to be able to observe this objectively.

Making air conditioning better for the planet

6 July, p 22

From Patrick Walker, Edinburgh, UK

You highlight problems with the growing demand for energy-intensive air conditioning in a warming world. How about updating building regulations so that new air conditioning installations must be accompanied by solar panels? Peak cooling demand (and electricity consumption) can be expected to correlate with daytime maximum solar radiation and maximum solar panel output.

More ways to unite world to a common purpose

22 June, p 36

From Valerie Senyk, Saskatoon, Saskatchewan, Canada

I resonated strongly with Harvey Whitehouse's point that "if we are to mature into a global tribe, capable of solving global problems, we will also need leaders capable of crossing existing tribal divisions", and that this requires "ways that are grounded in science" to address our collective interests.

I believe another way of sharing our moral concerns would be for the world to recognise that our religions have all come from the same source, an unknown Creator that has continued to morally guide us. Thus, science and religion need to go hand in hand to help humanity recognise its oneness.

Fusion cash could have been put to better use

6 July, p 13

From Sam Edge, Ringwood, Hampshire, UK

Our climate and biodiversity woes represent a threat greater than a world war. As we would with such a conflict, we need to spend our resources wisely on projects that will reap rewards immediately, or at least within the 20 years or so we have to make the biggest impact.

For example, the estimated €20 billion cost of the vast ITER fusion experiment, which I suspect is a vast underestimate, could have been used to subsidise the replacement of 8 million domestic gas boilers with heat exchangers in lower-income households. This would have led to energy cost savings for them, social security and healthcare system savings for everyone, large reductions in greenhouse emissions and a lessened reliance on despotic governments' control of gas supplies.

It would also have created far more employment and driven down the cost of the technology, compounding the gains. If private concerns want ITER to continue, they should fund it, since they are the ones hoping to profit.

A very cool idea, but will it be recyclable?

22 June, p 12

From Ian Gammie, St Albans, Hertfordshire, UK

The cool fabric for clothing that you describe may be rewarding for the scientists who designed it, but could it be damaging to the environment? Its three layers – wool or cotton, silver nanowires and polymethylpentene – could be a nightmare to recycle, particularly as many people wear fashionable items for a short period and then discard them. It would be fine to use this material in buildings, but not clothing.

No aspect of life is totally safe, including alcohol

Letters, 6 July

From James Birdwood, Shipton Moyne, Gloucestershire, UK

I take issue with Dan Roach's assertion that there is no safe level of alcohol consumption. You could equally make the case that there is no safe level of driving or playing football or swimming. Perhaps there is no safe level of being alive, given it always seems to end badly.

Launch of the great red dot friendship campaign

1 June, p 40

From Charles Joynson, Rayleigh, Essex, UK

I have an idea related to David Robson's look at scientific rules of connection that could improve your social life. One way for pubs, parks, libraries and other social spaces to help would be to paint a large red dot on the ground. This would be a place where people who want to develop new friendships could meet.

What we need to prove is absence of consciousness

Letters, 6 July

From Graham Jones, Fochabers, Moray, UK

Recent talk of consciousness in various organisms has got me thinking. Rather than trying to investigate whether organism X has consciousness, surely a more ethical standpoint would be to assume by default that they are all conscious, so any investigation should be reversed. I suspect it would be hard to prove the absence of consciousness.

Would a Dyson sphere be a monumental own goal?

Letters, 29 June

From Guy Cox, Sydney, Australia

There are two problems with arguments in favour of Dyson spheres, massive structures that advanced alien species might build to capture all of a star's energy. First, long before a civilisation could build one, the issue of hydrogen fusion would have been solved and so abundant energy would be available. Second, if the aliens' star system were anything like ours, putting a Dyson sphere in place would lead to the extinction of all higher life, including them – which doesn't seem like a bright idea! ▮

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The mathematics making AI

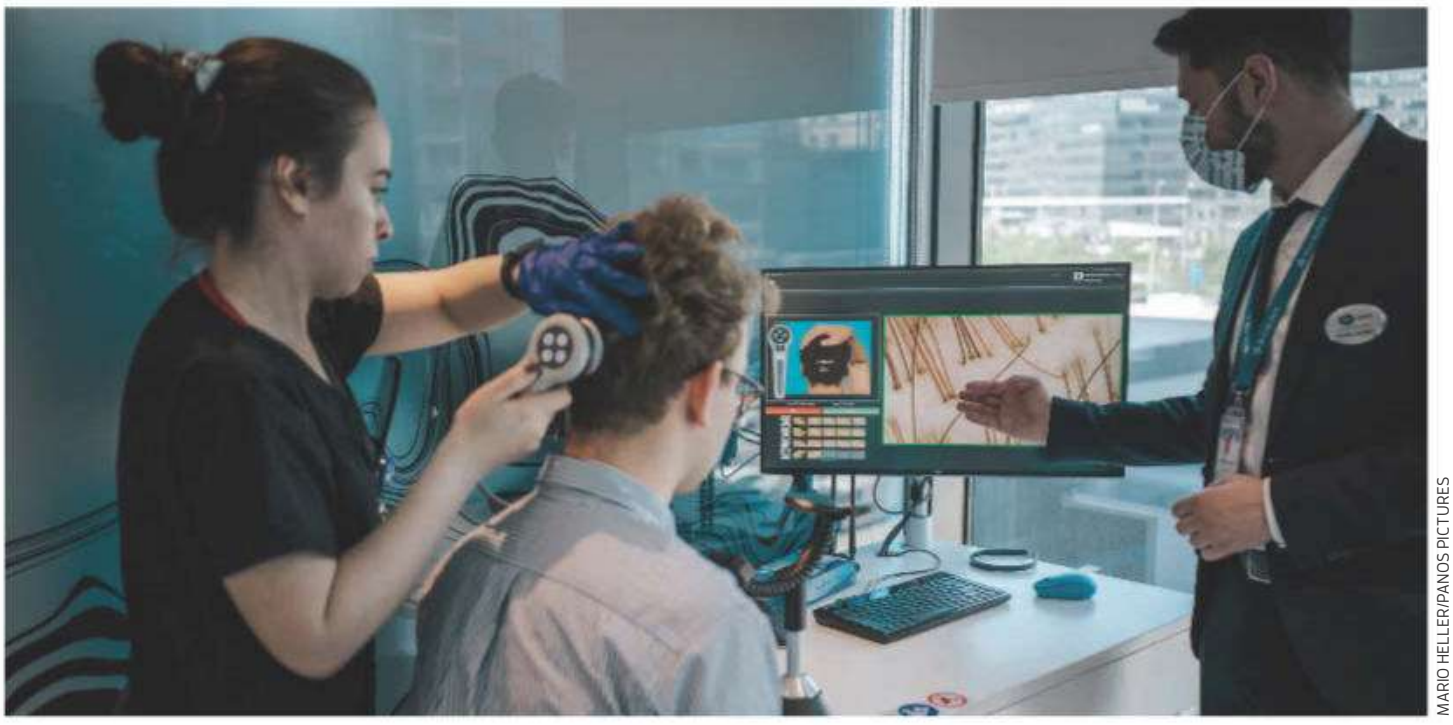
A skilful primer delves into what lies beneath the artificial intelligence revolution, but doesn't probe its ethical heart, says **Christie Taylor**

Book

Why Machines Learn

Anil Ananthaswamy

Allen Lane (UK); Penguin Random House (US)



MARIO HELLER/PANOS PICTURES

AS SOMEONE who writes for a living, I routinely feel assaulted by the onslaught of generative artificial intelligence. How long before I become a mere massager of prompted paragraphs, the joy of creation abandoned in favour of more, faster, cheaper?

Anil Ananthaswamy's *Why Machines Learn: The elegant maths behind modern AI* won't tell me or you about the future of AI in our society, nor what we should do about it. But whether you regard the algorithms used in facial recognition, healthcare decision-making tools or ChatGPT as an enemy or a way to improve your life (or profits), you will come away from this book knowing more about how they work.

Ananthaswamy is a science journalist, and a former *New Scientist* editor. This book came about after he got so excited while learning how ChatGPT's mathy engine creates outputs that he felt – as many science journalists do – an immense need to share that with us. The mathematics behind AI is simple, he says, the kind "one learns in high school or early in college", which makes it even more amazing that it can do so much. He illustrates the book with equation after equation as he explains exactly how we got here.

We begin in 1958 with the Perceptron, a simple classifying machine that eventually gave rise to neural networks. It was also an early instance of AI hype, as the US Navy (which partly funded it) bombastically pledged that the Perceptron "will be able to walk, talk, see, write, reproduce itself and be conscious of its existence".

It didn't, of course, but the Perceptron, modelled after a single neuron in the human brain, could learn to do some things, such as identify letters of the alphabet and sort unhealthy blood pressure readings from healthy ones in a patient dataset.

From there, we learn the mathematics of sorting, filtering, encrypting and identifying that

"The mathematics behind AI is simple, which makes it even more amazing that it can do so much"

algorithms now perform in countless real-world settings, even before the rise of word and image-generating tools. Think working out efficient delivery routes for packages, sorting penguins into species based on physical traits or how machine learning is used to check X-ray images for cancer.

It is a hard needle to thread: the book has to catch a non-scientist up on mathematics they may not have seen in decades, then tell a story. We relearn vectors, those quantities that have both size and direction. And we review matrices, derivatives and probabilities. But you soon get to much stranger conceptual spaces, where the equations turn into mostly letters and symbols implying multiple, even infinite, dimensions.

Ananthaswamy is a gentle teacher, repeating concepts in new contexts as needed. Even so, I struggled, letting my eyes breeze past equations until I was safely back among words. But this book works even if you do that. Ignore the equations and you will still learn the logic: AIs iterate, ingesting training data until they produce the most acceptable answer, guided by engineers and their own error calculations.

Ananthaswamy also chronicles the breakthroughs of early and later pioneers: Geoffrey Hinton had this insight, OpenAI's Ilya Sutskever that one, and so on. We learn about the roadblocks that led to the first "AI winter" in the 1970s, when research funding and corporate interest dried up, and the solutions that fostered the

Machine learning is key to developments in medical diagnostics

productive decades that followed.

Yet we land in the year 2023 with Ananthaswamy pondering whether the newly released ChatGPT might have the "theory of mind" that allows humans and some animals to infer what's going on in the thoughts of their fellows. This coda feels unearned, contradicting the logic of pattern-matching and probabilities from the preceding 400 pages and dipping a toe too briefly into a much, much bigger conversation.

Ananthaswamy is also perhaps too cautious in his assessment of how machine learning and other AI may fit into our lives. He thinks it inevitable that algorithms will be everywhere, "for good and for bad", but leaves it at that. Yet there are many other books to read if you are more concerned about the stakes of our current algorithmic obsession. At its heart, this is a manual more than a philosopher's text, a solid foundation to bear you into the weird, increasingly synthetic-feeling future. ▮

A peek inside

Nine profiles of neurodiverse people reveal their creative and imaginative worlds, finds **Eleanor Parsons**

Book

Nine Minds

Daniel Tammet

Wellcome Collection

HOW do you see inside the mind of someone else, how they really experience the world? Often, our mental shortcuts let us assume that everyone encounters it as we do.

But they don't: we all experience the world differently. And that is where reading or listening to other people's stories helps. In *Nine Minds: Inner lives on the spectrum*, Daniel Tammet, himself autistic, creates narrative portraits of nine neurodiverse people, setting out to explore "worlds so much richer than the dry, bland accounts… in texts captive to neurotypical ideas of autism" while evading "limited clichés, defying outdated prejudices". In this, he very much succeeds.

We meet Warren, a British police officer, who investigated 92 murders in seven years: in all but one case, the killer was convicted.

The message of *Nine Minds* is that there is no such thing as a single neurodiverse experience

Then there is Vaughan, a hand and wrist surgeon who "liked to think that certain autistic traits – tremendous focus, attention to specifics, imaginative somersaults – had played their part in [his] family's flourishing".

Creativity is a theme: Amanda, who wrote her thesis on the autistic poet Les Murray, describes how aspects of autistic thought are especially conducive to creativity, such as "inventing and playing with words… revelling in rhyme and the repetition of sounds; listing, arranging, classifying". Author Naoise relates how she wrote her debut novel in an "associative, cumulative, almost magical way". Engineer Ayo imagines lifelike, walking buildings of the future that can respond to the position of the sun and weather.

Tammet, who has written nine other books, including his memoir *Born on a Blue Day*, skilfully gives each portrait colour and personality so they zip along, with loves, joys and challenges effortlessly woven together in an engaging but sensitive style.

One common refrain is the damage that ignorance causes neurodiverse people. This is most shockingly illustrated when we meet Billy, a non-verbal adult who was diagnosed with autism as a toddler in the 1990s. His story, told through his mother Eve, details uncaring and dismissive attitudes from the medical profession. When Eve asked how to help Billy learn to communicate his needs, wishes and thoughts, for example, she was met with incredulity. "What thoughts?" asked the specialists.

Autistic people are pushing back against these negative stereotypes. Researcher Kana used her experience of crushing loneliness at university in Tokyo as her starting point to investigate loneliness in autistic people, setting out to overturn long-held beliefs that autistic people prefer to be on their own and so don't feel lonely. Her research, published in 2022, found that loneliness increases when autistic people try to conform to neurotypical social behaviours.

There is still a way to go. When I read how Kana was initially misdiagnosed with anxiety by a male psychiatrist, I wasn't surprised. Misdiagnosis is something many autistic people, particularly women, have experienced: a study published in April showed that prior to an autism diagnosis, 1 in 4 autistic adults, and 1 in 3 autistic women, received a diagnosis for a mental health condition that they perceived as a misdiagnosis.

While most of the profiles are a wonderful evocation of a person's life, some are less successful, staying at surface level. But this doesn't detract from Tammet's overall message that there is no single neurodiverse experience.

***Nine Minds* is an interesting book that eschews prejudices and stereotypes, showing, as Tammet puts it, the "power and beauty of the autistic imagination". If you would like to peek inside other people's minds, this is a great place to start.**

VINCENT CARCHIETTA-USA TODAY SPORTS/REUTERS

New Scientist *recommends*

Dhruv Shenai
Work experience
London

I have just seen **Inside Out 2**, an excellent animation that rejoins Riley, now 13, as she navigates the changes happening to and around her. Portraying the tight grip of anxiety and

cringing moments of embarrassment sets it up to be both intelligent and humorous.

This is a clever revisit by Pixar, with more timely, relatable humour rippling through its characters (pictured). And because each emotion is clearly a caricature, the film can have really silly moments without trivialising mental states or the neuroscience behind them.

The inclusion of careful little details, such as that Riley's rainbow T-shirt has now grown too small, show the care the film-makers put into creating an enjoyable and thoughtful experience.

In complete contrast, I am reading **L'Etranger** (**The Outsider**) by Albert Camus. It is the ultimate existential novel, one that challenges conformity and the meaning of life. Clearly an intellectual and emotional heavyweight, Camus is also uniquely stirring and insightful.

DISNEY

The games column

Keep it real In *Still Wakes the Deep*, you play as a Glaswegian electrician on a 1970s oil rig in the North Sea that is soon beset by an eldritch horror. But the well-crafted period setting makes me wish I could linger in mundanity, says **Jacob Aron**

Jacob Aron is *New Scientist*'s news editor. Follow him on X @jjaron

THE CHINESE ROOM

There are monsters on the Beira D oil rig – and you must evade them

THERE is a genre of video games known, in slightly derogatory fashion, as "walking simulators". The label has its roots in the combat-heavy nature of most video games, where pushing a button to pull a trigger provides the bulk of player engagement. As a reaction to this norm, walking simulators put the guns away and simply ask players to explore a space, perhaps with some light puzzle-solving, but mostly to piece together a story or experience from the environment.

Developer The Chinese Room is possibly the leading creator of walking simulators, with critically acclaimed hits including *Dear Esther* and *Everybody's Gone to the Rapture,* but – and I may have to whisper this bit, lest hordes of angry gamers descend on me – I found them both incredibly dull. Despite this, I was keen to give their latest title, *Still Wakes the Deep*, a go – mostly because of its setting: a 1970s North Sea oil rig beset by an eldritch horror.

This game immediately establishes its period visually, with a tatty industrial look and posters from the National Front (a fascist political party in the UK), and through sound, from the crashing noise of the ocean to naturalistic Scottish dialogue that could have been ripped from an Ian Rankin novel. In fact, the game is so committed that it offers a choice of subtitle options – one that renders the dialogue as spoken, and another "translating" it into more traditional English.

"The game has naturalistic Scottish dialogue that could have been ripped from an Ian Rankin novel"

The first half hour or so is The Chinese Room in full walking simulator mode: ground the characters before the tentacles come out. You play as Caz McCleary, a Glaswegian electrician on the Beira D oil rig, and you are quickly introduced to a cast of characters ranging from a union-hating overseer to a kindly chef.

Just as I felt I was getting a handle on everyone, an explosion kicks off the plot. It is clear the drill has hit something bad, and both the rig and its occupants start to come apart at the seams. People are transformed into strange, twisted monsters but seem to remember who they are, calling out to Caz as they chase you.

With no ability to fight back, the game boils down to getting from A to B without being eaten. This involves a basic traversal of the crumbling rig, along a path so linear it may as well be on rails, and even more basic puzzle-solving. I must have turned the same wheels or pulled the same levers a dozen times. Adding to the repetitiveness, each time you fix part of the rig trying to get out alive, a character will come on the radio and reveal the next thing that needs repairing. I suppose it fits Caz's character well, but I soon felt I was ticking off a list of chores.

This wasn't helped by *Still Wakes the Deep*'s monsters being, well, a bit silly. Although the game is full of horror tropes, from ambiguous moans to flickering flashlights, I never felt scared. I ended up glad for the run button, not to escape the monsters, but to get to the next section faster.

It is ironic that the last thing I saw after completing the game was a "Walking Simulator" achievement – apparently given for having run for under 10 minutes during the game. This might be a bug, because I know I spent much longer holding down the run button, but it made me think I would have preferred to have spent more time in the game's first 30 minutes, absorbing its unique atmosphere. Maybe there's something to this walking simulator idea after all. ▮

Games

Still Wakes the Deep

The Chinese Room

PC, PlayStation 5, Xbox Series X/S

Jacob also recommends...

Games

Alien: Isolation

Creative Assembly

PC, PlayStation 3 and 4, Xbox 360 and One, Nintendo Switch, Android, iOS

If you want blue-collar horror on a failing outpost, look no further than the best Alien *game ever made.*

BioShock

2K Boston and 2K Australia

PC, PlayStation 3, Xbox 360, iOS

Still Wakes the Deep *takes inspiration from* BioShock*'s underwater city of Rapture, one of the best and creepiest environments in gaming.*

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- Yemi, Biomedical Science BSc student

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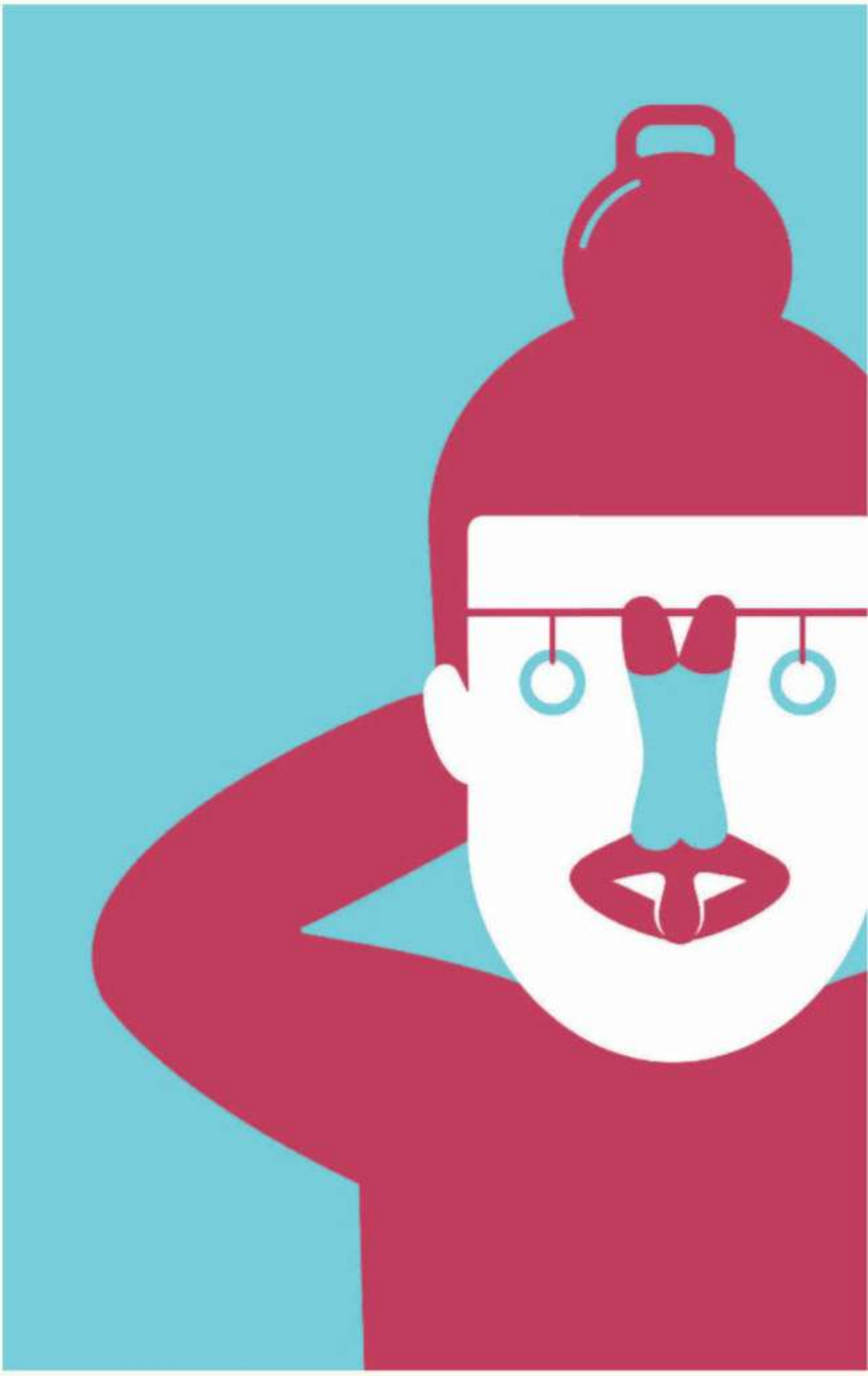


NOMA BAR

OVER the next few months, 3 billion of us will tune in to watch the feats of the greatest athletes at the Olympics and Paralympics. When it comes to doing exercise ourselves, however, things are more equivocal. Only around a quarter of adults in the US and UK hit the recommended levels of physical activity. Why does something that is so good for our physical and mental health feel like a chore to many?

This is just one of many big questions surrounding exercise. Are there any shortcuts to getting fit quickly, for instance, and what is the optimum dose of exercise for our long-term health? Now, we are finally getting answers thanks, in part, to a wealth of data from wearable fitness trackers. New findings are also shining a light on whether the time of day alters the impact of workouts, if there are ways for the couch potatoes among us to hack their motivation, and whether it matters if workout classes are online rather than in person. Over the next 11 pages, we take a deep dive into eight questions you need to understand about exercise and its influence on our bodies and minds – children included. So read on to discover a fitter you.

WHAT IS THE QUICKEST WAY TO GET FIT?

WATCHING an athlete at their peak is thrilling. Fulfilling one's own athletic potential, not so much. Getting fit is hard and painful – or so we assume. But that isn't necessarily the case. In fact, research shows that anyone just starting to exercise more than they are used to will see improvements surprisingly quickly, regardless of the workout they choose. Better yet is the discovery that there are ways to speed up the fitness journey.

The key to improving fitness is, in essence, simple. You need to exceed your "habitual load", which is a fancy way of saying doing more activity than you are accustomed to. This will stress your body and force it to adapt.

When it comes to starting cardio exercise as a beginner, "one of the first things that happens is you get more blood volume", says Abbi Lane at the University of Michigan. Within 24 hours of working out, this increases by up to 12 per cent due to water retention, which increases the amount of blood plasma, boosting the amount of oxygen that can be supplied to the muscles. After two weeks of training, peak blood volume is normally reached, which is about 15 to 20 per cent higher in athletes than in sedentary individuals.

Energy-producing structures within our cells called mitochondria become more numerous and efficient around this time as well. Small blood vessels known as capillaries begin rapidly proliferating within muscles, too, improving the body's ability to deliver oxygen to tissues. One study found that capillary density expanded by about 20 per cent after two months of a cycle training programme.

These shifts enhance the maximum rate at which the body can use oxygen, a measure known as VO2 max, says Stuart Gray at the University of Glasgow, UK. Changes in VO2 max typically occur around six to eight weeks into training. By the third month, it can improve by approximately 10 per cent, he says.

Muscle also adapts rapidly. A single session of strength training increases the activity of genes within muscles involved in regulating inflammation and removing waste products that accumulate as a result of the stress of exercising. It doesn't take long to build muscle strength either, at least if you are a beginner. "Everyone gets stronger in their first three weeks because your nervous system learns how to talk to your muscles better," says Lane. With repetition, the nerve signals from the brain get quicker, and muscles become better at responding to them, generating greater force more rapidly, says Gray. Exercising also builds brawn by tearing muscle fibres, allowing them to build back stronger. In a sense, you literally become "ripped". This takes a bit longer, though, so the greatest improvements in muscle size and strength don't happen until about eight to 12 weeks into training.

All of this suggests that exercise should feel a bit easier within two to three months of your first workout. But several factors mean this varies from person to person. The most significant influence is genetics. Our genes determine about half our aerobic fitness, says Lane. "Some people, no matter how much they train, their VO2 max won't shift very much," says Gray. "Then, you'll get the very annoying people that will do the same training as you and their VO2 max will fly off the charts."

Age is another factor, with younger people adapting to exercise more quickly than older adults. Prior physical activity makes a difference, too, as people who have previously trained are able to rebuild muscle faster than those who are just starting out.

A wide range of exercises can improve fitness within a few months, provided they are done three to five times a week for about 30 to 60 minutes. For instance, 12 weeks of endurance training such as cycling increased muscle mass by 7 to 11 per cent, roughly the same as a strength training programme of the same duration. However, one regime seems to trounce all others in terms of getting fit quick – both from an aerobic and strength perspective – by stressing our physiology in just the right way to induce maximal adaptation.

High-intensity interval training (HIIT) involves exercising at near maximum effort in repeated bursts of up to a minute, with short rests in between. This regime was devised in the 1990s by Izumi Tabata and his colleagues at the National Institute of Fitness and Sports in Kanoya, Japan. They showed that a 4-minute workout, with repeated cycles of 20 seconds ›

of intense work then 10 seconds of rest, done five days a week for six weeks resulted in greater aerobic improvement than moderate, hour-long workouts done over the same time frame.

Since then, many trials have confirmed the power of HIIT. "If you want a quick increase [in fitness] over four to six weeks, purely intervals would do the job," says Lane. The key is working as hard as you can during the intense intervals. Just six HIIT sessions over two weeks significantly improves VO2 max and endurance capacity, but, remarkably, a 2021 study found similar improvements could be achieved if these HIIT sessions were squeezed into a five-day period.

Adam Sharples at the Norwegian School of Sport Sciences in Oslo says beginners should start with two to three HIIT sessions per week. You can intersperse these with longer-duration endurance activities, such as jogging or swimming, to further boost results, he says. Once you notice that your strength has plateaued with HIIT, you can add two or three full-body strength-training sessions, says Lane.

However, the best exercise is ultimately the one you will be able to stick with, not necessarily the one that leads to the quickest improvements. "We sometimes get in the weeds with what is the perfect plan, but I think for most people, we just need to get out there and get moving," says Gray.

The trick is to continuously challenge yourself. If you do, you may be surprised to discover your own peak performance.

Grace Wade

HOW MUCH EXERCISE IS TOO MUCH?

THE BENEFITS of exercise are so great that if it were a drug, it would be a miracle cure. But what is the optimal dose for better health: are people who run ultramarathons, lift weights every day or swim the English Channel better off than those who just go for gentle walks? And is it possible to overdose? Now, thanks to large-scale studies that follow cohorts of people over long time periods, we can finally find the answers.

Firstly, these studies show a dose-related effect of exercise, with the health benefits kicking in at even low levels of activity. For instance, a 2022 study that followed more than 400,000 US adults over nearly two decades found that 1 hour of aerobic exercise per week was associated with a 10 to 20 per cent lower risk of dying during the study period. The good news for sedentary types is that the biggest gains come from changing from doing nothing to doing something (see chart, below). And the health benefits for people aged over 60 seem to be stronger than for adults below this age, for a given amount of exertion.

We can also look into the impact of different intensities of physical activity. Moderately intense activities are things that significantly raise your heart rate, such as brisk walking or playing a fun game of badminton, where you can still talk but not sing. Activities that make you out of breath, such as riding a bike fast or hiking in the mountains, are classed as vigorous. A number of studies show that you don't need to be a committed athlete to gain near-maximal health benefits from either. These can be achieved surprisingly easily, from doing around 150 to 300 minutes per week of vigorous physical activity, 300 to 600 minutes at moderate activity levels or an equivalent combination of both.

After this point, it is a case of diminishing returns for additional health benefits – but the devil is in the detail.

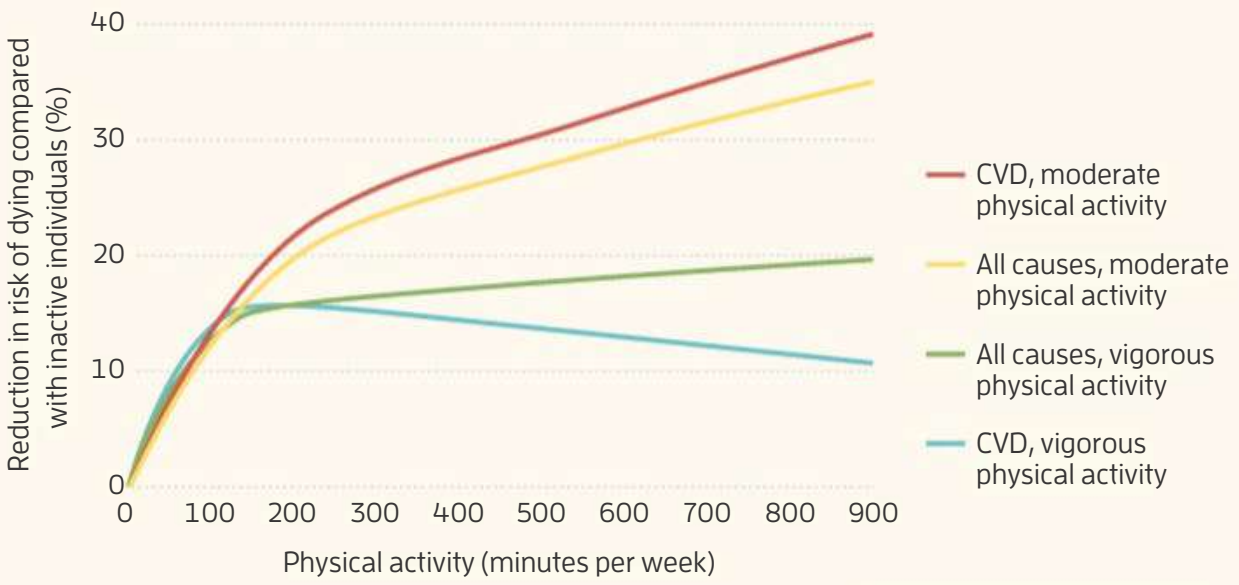
For moderate-intensity exercise, more is still better: your risk of dying early, say from a heart attack, will keep decreasing the more you do. "There's no such thing as too much exercise if it's moderate-intensity aerobic exercise," says Duck-chul Lee at the University of Pittsburgh in Pennsylvania.

Vigorous aerobic exercise may be a different matter, but it is a confusing picture. Some studies from around a decade ago seemed to show associations between participating in extreme events like marathons, ultramarathons and Iron Man distance triathlons and having an increased risk of cardiovascular problems.

However, in a 2016 study of more than 55,000 runners, Lee and his colleagues found that the most extreme runners weren't at a higher risk of death than those who ran less. They weren't getting any extra benefits – at least not in reduced mortality risk – but nor were they worse off. A 2022 study of 116,000 US adults found a similar pattern. Likewise, in a study published in May, researchers found that the first 200 men to run a mile in less than 4 minutes lived, on average, 4.7 years beyond their predicted life expectancy.

Tortoise vs the hare

Even a small amount of physical activity boosts long-term health, but this effect tapers off with increasing time spent exercising, especially for vigorous-intensity exercise



SOURCE https://pubmed.ncbi.nlm.nih.gov/35876019/

CVD = cardiovascular disease

So the "extreme exercise hypothesis" – that excessive exercise, particularly high intensity training, can harm overall health – "is still a hypothesis, so not confirmed yet", says Thijs Eijsvogels at Radboud University Medical Center in the Netherlands. He warns that many studies use questionnaires to find out how much people exercised, which is unreliable due to inaccurate reporting of activity levels, and most include only a small number of people who did extreme amounts of exercise, so the apparent harms come with large uncertainties. Research is now under way that uses more objective measures like pedometers, along with larger sample sizes, so we may soon have a clearer picture.

As for resistance exercises like weightlifting, there is even less evidence of the harms of overdoing it – partly because there are no validated wearable fitness trackers that can keep a record of muscle exertion. Nevertheless, in 2023, Lee and a colleague reviewed the limited available data. They found an optimum of 40 to 60 minutes of training per week, above which the cardiovascular benefits don't increase and may decrease. Lee is now starting a controlled trial to see if this apparent pattern holds true.

Finally, there are also the psychological impacts of exercise. In general, it is beneficial, says Lee. "It lowers the incidence and prevalence of depression, anxiety and so on." However, in some cases, it may take over a person's life to an unhealthy degree.

"There is growing evidence of an exercise addiction," says Débora Godoy Izquierdo at the University of Granada in Spain. This isn't about simply training a lot and enjoying it, she says, it is about whether you can manage your enthusiasm for exercise and still participate in other activities like work, socialising and family life. "If you cannot manage your passion, then you are in trouble," she says.

What does all this mean for aspiring athletes? The first thing to note is that the possible health risks are only relevant to those who are doing a lot of high-intensity exercise. And even for extreme athletes, Eijsvogels says there is no general recommendation to stop or ease off, because the data remains weak.

For most of us, who aren't doing anything of the kind, more exercise is good – and you might not need to do as much as you think to gain the health benefits.

Michael Marshall

"You don't need to be a committed athlete to gain near-maximal health benefits"

RYAN WILLS; RAJESH JANTILAL/AFP VIA GETTY IMAGES

WHAT IS LOST – AND GAINED – WHEN YOUR GYM INSTRUCTOR IS AN IPAD?

I HAVE NEVER attended the same gym as Eric Drinkwater, a sports scientist at Deakin University in Melbourne, Australia. In fact, we live over 1000 kilometres apart. But as soon as we start talking on the phone, we discover that we share the same gym instructors, located on the other side of the world in Los Angeles.

We are just two members of a growing cohort training online with coaches they have never met, uncoupled from timetables and venues. This is a phenomenon that was waiting to erupt since the advent of the internet and smart devices, and the covid-19 pandemic provided the impetus for it to explode.

In 2016, fitness apps were downloaded just over 200 million times. In 2022, in the wake of the pandemic, the figure was nearly 900 million, with the number only dropping slightly in 2023. A great deal of gyms were forced to temporarily close as the coronavirus swept the world, but when they reopened, many people's exercise regimes had changed and some, like me, never went back.

But does it make a difference if you exercise alone at home rather than with a group or in a busy gym? After all, there are many well-documented benefits of working out alongside other people. "The social aspect of fitness training is important to many," says Drinkwater. For instance, a 2021 study by Emma Cohen at the University of Oxford and her colleagues found that the social nature of exercising with others at parkruns – free 5-kilometre community events that take place around the world – was associated with greater enjoyment, which in turn was linked ›

"Doing yoga online means I can work on my moves without fear of judgement"

to faster run times without a corresponding increase in perceived effort.

A lot of what allows us to feel connected to other people happens outside of our conscious awareness, through the alignment of our bodies, expressions and movements, says Cohen. "This can facilitate a strong sense of oneness, or connection," she says. "And, as social connection is normally a pleasurable experience, this can enhance the enjoyment of the activity, motivating us to keep at it."

But those of us who exercise solely in the company of an online instructor don't necessarily miss out on these connections. "This is the most fascinating and yet-to-be-explored scientific frontier of having an iPad for a coach – the psychology of how the best of the new apps plug into our social needs, to build an illusion of being part of a group," says Drinkwater. The app that he and I both use, for example, offers a range of coaches whose prerecorded sessions we can choose from, throughout which there is banter and encouragement.

Something that has baffled me, but which has made online exercise classes sustainable, is the unexpected connection I feel to these instructors. Technically, this is known as a parasocial relationship, a feeling of connection to someone who doesn't know you exist – something that is tapped into by online platforms that offer trainers with a diversity of personalities and backgrounds so that everyone can find someone with whom they have a rapport. "The more these apps foster a sense of connection, the better the adherence," says Niamh Mundell, also at Deakin University.

This could help answer another question on my mind and Drinkwater's: why we push ourselves so hard in online classes, even though the trainer can't see us. "It's just me and the bike, but I always work harder than if I was following a programme I'd designed myself, even though the trainer cannot see how hard I am sweating," says Drinkwater.

This productivity boost could be due what psychologists call the Hawthorne effect, where people increase their performance when they feel as if they are being observed. In order to tap into this, some exercise apps have features that rate how you are doing along with others who follow the same programme – for example, a "burn bar" that shows how your heart rate compares with others who have taken the same class.

Online fitness classes can also bypass some of the downsides of exercising with others, such as a sense of shame at being the worst in a group or thinking you are the wrong size. I love yoga, for instance, but find in-person classes daunting because I am not flexible. Doing yoga online means I can work on my moves without embarrassment or fear of judgement.

Exercise apps that recreate the ingredients of social connection and togetherness, while also reducing the negative effects of social comparison that can occur in real-world group settings, will capture some of the benefits of in-person group training, says Cohen.

While the pace of change and extent of disruption to the fitness industry has been dizzying, there is much more to come. "This space is evolving rapidly," says Mundell. "AI instructors are just around the corner." Who knows what exercising in virtual reality with an artificially generated avatar coach – designed specifically for our personality, cultural background and training needs – could help us achieve?

James Woodford

DOES SLOW RUNNING COUNT AS A WORKOUT?

FOR MANY runners, going fast is the whole point of pulling on their kit. But recently, the opposite approach has been booming: the slow-running movement, in which people meet for social, unhurried jaunts. This might be fun, but surely if there's no pain, there's no gain?

Not so fast, says a growing body of research. In fact, going at a more leisurely pace can bring a range of health benefits, from heart function to mental well-being, while avoiding the downsides of pushing your body to the max. It might even help you live longer – and, ironically, ultimately improve your personal best.

Slow running isn't about a set speed, it is about going at a pace that is slow for you – one that raises your heart rate, but leaves you able to chat. Technically speaking, your heart rate will be at 60 to 70 per cent of your maximum, says Rebecca Robinson, a private consultant in sports and exercise medicine and a keen runner.

This level of exertion – also known as zone 2 training – is meant to be fairly easy, so does it really count as a workout?

"Yes," says Steve Haake at Sheffield Hallam University in the UK. Energy expenditure increases linearly with running speed, so the total energy you use covering a fixed distance is generally the same, regardless of how fast you cover the ground, he says. "With slow jogging, it just takes longer."

This is why you can get many of the same benefits from walking as you can from running, if you have the time, such as a slower rate of biological ageing and a mental health boost. It is the cumulative energy expenditure that counts for many of the physiological effects of exercise, rather than the intensity of effort.

But the unhurried pace of slow running means it can provide things that high-intensity exercise doesn't. The speed at which you run affects what your body uses as fuel. If you are taking it slowly, your body can use aerobic metabolism, which depends on a good supply of oxygen from your lungs. This means you break down stored fat to supply most of your energy. "If I want to burn fat, then running slower is best," says Haake. At high energy intensities, when you are gasping for breath, the body flips to anaerobic processes and mainly breaks down carbohydrates and protein.

By metabolising fats better, zone 2 training can help us manage weight and insulin levels, says Robinson. Slower jogging can also help our cardiovascular system operate more efficiently, she says, by encouraging the heart muscle to develop, increasing the amount of blood it can pump, reducing resting heart rate and cutting blood pressure and cardiac stress.

In fact, some studies show that it might be more beneficial for your cardiovascular system if you exercise moderately, rather than pushing yourself to the max (see "Tortoise vs the hare", page 34). For instance, a 2022 study of the long-term health of more than 116,000 US adults found that the benefits of vigorous physical activity for cardiovascular health tailed off at high levels, unlike for moderate-intensity activity. The health benefits or otherwise of high-intensity exercise are still much debated (see "How much exercise is too much?", page 34).

Likewise, a 2020 study of 138 first-time marathon runners found that training for and completing the race, even at a slow pace, is equivalent to a four-year reduction in the biological age of the cardiovascular system, with slower running times associated with a greater reduction in age-related stiffening of the aorta, the large artery that carries blood from the heart.

There are mental boosts from taking things slowly too. While high-intensity training is renowned for the "buzz" of endorphin release, says Robinson, slow exercise outside provides its own kind of buzz. "We can be more mindful of our own feelings and of nature around us if we choose to exercise slowly outdoors," she says. "Because we can exercise at a conversational pace, it can be an important time to connect with the friends we work out with – helping our and their mental well-being."

But how might slow running fit into the life of someone whose goal is to clock up fast times? In fact, the practice is relied on by elite athletes. Many long-distance runners spend about 80 per cent of their training in zone 2, rather than at faster paces.

"As a runner myself, I love to run hard, high-intensity efforts, but I know that slow running is an important part of my programme," says Robinson. "It has specific physiological benefits for training and also enables recovery between harder workouts – trying to run hard every day ultimately overloads the body's ability to adapt and recover."

A varied training programme of low and high-intensity workouts and rest days allows runners to adapt until they can tolerate the high forces through their muscles, joints and tendons that allow strength and speed to develop, says Robinson. In other words, slow running can give you a suitable fitness base and body condition to allow you to raise the bar, if you want to.

The bottom line is that going slow can help you go fast – and might help you live longer too.

Chris Simms

CHELSEA GATES/UNSPLASH

"It might be more beneficial for your cardiovascular system to exercise moderately"

CAN YOU HACK YOUR MOTIVATION?

IF THE IDEA of exercise seems more attractive to you than the reality, you will identify with Jessica Howard. She had always nurtured the vague intention of running a marathon, but had struggled to get off the sofa. "I didn't run, I didn't move," she recalls. "I was a couch potato."

This all changed when, as a student at Bangor University in the UK, she took part in a special module on offer there that aims to tackle a key challenge many of us face when it comes to exercise: motivation. It turns out that there are tricks we can use to help us break bad habits and reach our goals.

Summoning the will to exercise is a huge challenge for most people (see "Why we don't like to exercise", right). This is particularly problematic in higher-income countries, which have twice the levels of inactivity compared with lower-income ones, and where many people aren't sufficiently active to stay healthy in the long term.

Certain barriers, such as ill health or a lack of suitable space and resources, can seriously restrict our capacity to exercise. For many, however, the battle is internal: we struggle to carve out the time. We may fully recognise the long-term benefits for our physical and mental health, but get drawn to things that bring more immediate rewards without the need to break a sweat – like slouching in front of the TV. At the heart of this is the idea of "delayed gratification" – a common barrier to many behavioural changes.

The "Born to run" module at Bangor aims to find ways to overcome this, by teaching students how to build new habits more effectively, specifically focusing on the goal of running a marathon. "The idea is that, by employing certain psychological theories and techniques, you can achieve challenging goals that you would not have thought possible," says Frances Garrad-Cole, the module's organiser. "Part of achieving difficult goals is being able to motivate yourself when you have setbacks, don't feel like it, have competing interests and so on. This module teaches the ways to work through those challenges to stay motivated."

A good place to start is with little psychological tricks known as "nudges". The aim is to remove any inconvenience that might offer an excuse to opt out. You might put your running shoes by the front door the night before your morning jog, for example. "So when the alarm goes off, you don't think about it – you've nudged yourself into behaviour change," says Garrad-Cole.

It also helps to be aware of the different forms of motivation and their effects on behaviour. Extrinsic motivation comes from external incentives. You decide to run a marathon because you think it might look good on your CV, for instance, or to support a charity. Intrinsic motivation, in contrast, comes from the activity itself. If you learn to find pleasure in exercise because it helps to clear your mind and combat stress, that would be an intrinsic motivation. Research suggests the latter is more likely to help us form a new habit, such as regular training.

Another key theme of the module is "mindset" – whether you believe the qualities necessary, say, to run a marathon are innate and immutable or that they can be nurtured over time. You might assume that you don't have the necessary reserves of willpower to do the training. People with "fixed" mindsets tend to interpret any failure as a sign that they don't have it in them to succeed. People with "growth" mindsets are more resilient and see their disappointments as an opportunity for learning – which helps them achieve greater success in the long run. Our mindsets are malleable: learning about the brain's capacity to change and adapt to new behaviours can help us adopt a growth mindset.

One more practical way to stay on track is to create a training plan that can be broken into sets of larger and smaller objectives using SMART principles – which stands for Specific, Measurable, Achievable, Relevant and Time-bound. If your aim is to improve your running, that might include signing up to a parkrun each Saturday or using an app to set realistic targets to increase your total distance each week.

Finally, there is accountability. The Bangor module begins in January and by the Easter break, many students are training regularly. The holiday period presents new challenges, however, as they lose the structure provided

Why we don't like to exercise

Inactivity is pathological: it can literally kill us, eventually. So why do so many of us struggle to find the motivation to exercise? Given its huge health benefits, you would think that we would all be champing at the bit.

The problem lies in the term "exercise", argues Daniel Lieberman at Harvard University. We never evolved to exercise – we are hardwired for moderate exertion throughout each day, not triathlons or treadmills. And there was never any evolutionary selection pressure to make us like exercise. Our ancient ancestors had to cover long distances every day in order to survive, so not exercising was never an option. On the contrary, there was probably an evolutionary advantage for those who avoided needless activity when they could, conserving precious energy.

Alison George

by regular lectures, seminars and group runs. Psychologists refer to that external support as "scaffolding" and one of the key lessons is that you have to construct your own.

You could use a tracking app, for instance, where your performance is visible to others. This can help you feel answerable for your actions, and to get encouragement when you stick to your schedule.

The results speak for themselves. In the first year the course was offered, none of the students had run a full marathon before – and many, like Howard, barely exercised at all. By the end, the majority completed either a full or a half-marathon. "It's incredible watching these students change," says Garrad-Cole.

Surprisingly, she has found that the module helps improve the participants' self-compassion – their ability to treat themselves kindly when they face disappointments. This is important, since self-compassion can help us cope more constructively with stress and is associated with better mental health.

This approach certainly worked for Howard, who has since completed a number of marathons and become a running coach. "The module changed my life," she says. The lessons she learned could do the same for you.

David Robson

"There are tricks we can all learn to break bad habits and reach our goals"

HOW FAST DO WE LOSE FITNESS?

FALLING off track from your workout routine is inevitable. Life happens. You go on a trip. You sprain your ankle or start a new job. Then, once you find the time to resume training, you feel weak and out of breath. It can seem like all your good work has been for nothing. But that isn't the case. Although we do lose fitness shockingly fast, it turns out that we don't simply go back to square one. What's more, even when circumstances keep you from your regular routine, there are various things you can do to minimise the losses.

How rapidly fitness declines depends on what aspect of it you consider. The news is worst when it comes to aerobic fitness. Evidence suggests that VO2 max, the maximum rate at which the body can absorb oxygen, drops significantly after a mere 12 days of inactivity, largely due to a roughly 10 per cent decrease in the amount of blood your heart can pump with each beat. Some changes occur even sooner. For instance, blood volume decreases after two days of rest. After a month, we have fewer capillaries delivering oxygen to our muscles too, possibly due to changes in levels of a protein that affects capillary formation.

In a preprint paper from June, Adam Sharples at the Norwegian School of Sports Sciences and his colleagues found that improvements in VO2 max from two months of training evaporated after three months of inactivity. "With aerobic fitness, if you don't train for months, you lose it, and it is like starting over almost every time," says Abbi Lane at the University of Michigan.

Muscles are a tad more resilient to inactivity. Notable declines in strength occur within around two to three months of stopping exercise. Research shows that eight weeks without training can cause upwards of a 12 per cent decrease in ›

strength. Changes may happen even faster, though. Another study in people aged around 70 found that participants lost, on average, 4 per cent of muscle mass in their legs after decreasing their daily step count by 75 per cent for two weeks. And some of the knock-on benefits of fitness were reduced too: participants became more resistant to insulin, which controls blood sugar levels, and had higher levels of unhelpful immune activity called systemic inflammation.

However, thanks to a particular type of muscle memory, all is not lost. Sharples and his colleagues found that strength training increases the activity of several genes that make muscle proteins, and that these genetic changes can endure for months after training stops. Participants in a 2018 study saw a 7 per cent increase in muscle mass after seven weeks of resistance training. These gains mostly disappeared once they stopped training for seven weeks. Yet their muscle mass grew by 12.5 per cent, on average, after an additional seven weeks of resistance training. This suggests that "muscle might remember [previous training] and get back those [lost] gains more quickly than if you had never experienced them before", says Sharples.

Admittedly, many of these studies include only a few participants – the 2018 one, for example, involved just eight people, all men. But they may also represent worst-case scenarios because they tend to explore what happens when people stop training entirely. The picture is probably different if you just decrease your exercise. "If you can keep the intensity of your workouts, even if you have to cut your volume by 50 per cent, you can minimise your fitness losses," says Stuart Gray at the University of Glasgow, UK.

And even if you can't find time for conventional exercise, maintaining any level of activity will help. For example, a 2019 study found that vigorously climbing stairs for 20 seconds, three times daily on three days of the week improved participants' VO2 max by about 5 per cent, on average, after six weeks.

With this in mind, Lane recommends incorporating short bouts of movement – what she calls "exercise snacks" – into your day. "Anything you can do counts, so find ways to be creative, whether it is running for the bus, doing yard work or playing in the pool with your kids," she says. The key is to use your muscles in any capacity that works for you. So, if you are injured, it is best to seek advice from a physical therapist who can recommend appropriate, lower-impact exercises such as swimming or cycling.

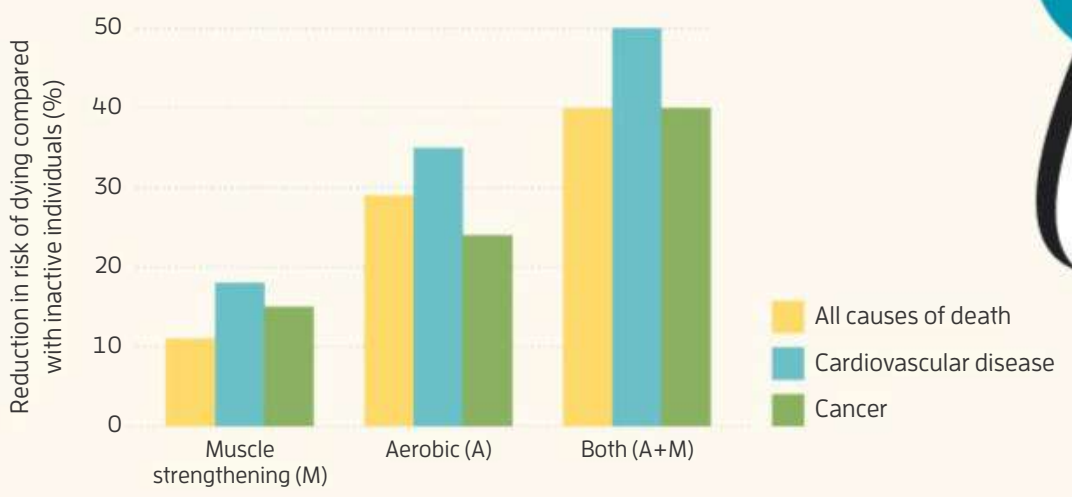
On an even more positive note, you may be able to mitigate fitness declines with a simple dietary intervention, as there is evidence that omega-3 fatty acids can help reduce the rate of muscle loss due to immobilisation. This is no substitute for exercise, but it might give you a helping hand when life gets in the way. **GW**

"Thanks to muscle memory, all is not lost when we take a break"

NOMA BAR

Health boosts

Physical activity keeps us healthier for longer. The effects are good for people who do muscle-strengthening exercises at least two days a week, better for those who do at least 150 minutes of moderate aerobic activity per week, and best of all for those who do both



SOURCE https://www.bmj.com/content/370/bmj.m2031

WHEN IS THE BEST TIME TO EXERCISE?

USAIN BOLT smashed the 100-metre sprint record at the 2009 World Championships in Athletics in Berlin in a floodlit stadium under an inky night sky.

This was no coincidence: when it comes to sporting prowess, timing matters. For activities relying on sheer muscle power and endurance, evening or late afternoon are when most world records have been set, probably due to assistance from peaks in the daily rhythms of a number of the body's key physiological outputs. But what about everyday exercisers? Is there an optimal time of day, or month, to get the most out of workouts and reduce the risk of injury?

"Whichever aspect of sport you look at – whether it's sports medicine or exercise response – time of day matters," says Qing-Jun Meng at the University of Manchester, UK. Later afternoon or evening is when our body temperature peaks, resulting in faster metabolic reactions and nerve signal transmission compared with the early morning. Connective tissue is also more flexible in the afternoon, while our reserves of glycogen – the biochemical energy source our muscles draw on during moderate to intense exercise – have had time to be replenished.

Other physiological parameters also vary over the 24-hour period, which could be relevant for exercise: testosterone secretion peaks at around 9am; coordination tends to be best at around 2.30pm; reaction times are fastest at around 3.30pm; cardiovascular efficiency, muscle and grip strength peak at 5 to 5.30pm.

"Circadian rhythms exist in almost all cells of the body and regulate key processes relating to exercise and metabolism," says Meng. "Depending on what time you exercise, your muscle, fat and other cells will also be in a different state, and they will respond to exercise differently."

Indeed, a recent study by Renske Lok at Stanford University in California and her colleagues found that, on average, Olympic swimmers are more than a third of a second faster if they compete in the evening rather than in the morning. "In 40 per cent of [swimming] races, the time-of-day effect is bigger than the difference between finishing first or second," they wrote.

For sports involving more technical skills, such as tennis or soccer, peak performance tends to arrive a little earlier – possibly because our cognitive abilities usually peak in the late morning or early afternoon. Soccer players juggle and chip the ball with the greatest precision at around 4pm; tennis players' serves tend to be faster in the evening, but more accurate in the morning. Of course, these timings are based on averages – in reality, "larks" who tend to wake early and be more active in the mornings will be at their best earlier, while "owls", who naturally come to life in the evenings, will peak later.

What are the implications of all this for how the rest of us time our exercise? Last year, Fabienne Bruggisser at the University of Basel in Switzerland and her colleagues pored over the evidence from 26 previous studies and found little to support or refute the idea that training at a specific time leads to better performance or improved health outcomes.

They did, however, find some evidence to support training at the same time of day as a race or competition to improve physical performance at this time. In other words, morning training improves morning performance more than evening training does, and vice versa. However, given that the studies only included young male participants, it remains to be seen whether such conclusions apply to the general population, the authors said.

Women may have a further layer of complexity to consider. In recent years, several women's soccer teams, including Chelsea FC Women, have started tailoring their players' training programmes around their menstrual cycles, claiming that doing so boosts their performance and reduces their risk of injury.

"The theory is that when oestrogen is high and progesterone is low... that's an anabolic environment; it's a good [time] to work hard," says Stuart Phillips at McMaster University ›

TECHNOTR/GETTY IMAGES

in Canada. Yet when he and his colleagues recently reviewed the evidence for an influence of menstrual cycle phase on exercise performance, they found it was "remarkably thin". "The evidence that we do have suggests that there's no merit to it," says Phillips.

Even so, he doesn't dismiss recording symptoms and using them as a guide to scheduling training. "I know some women are genuinely adversely affected at certain phases of their cycle with menstrual-related symptoms: cramps, backaches, a lack of motivation, fatigue, etc. And for women athletes that do experience symptoms, trying to manage them and making their coach aware of them is a great thing," he says.

"But as for a blanket, 'this-is-the-way-you-do-things'-type approach, there's no consistent pattern to performance when it's studied systematically, and we know gold medals and world records have been set at different [menstrual] phases, and on and off the contraceptive pill."

Meng believes there may be yet other factors to consider. Generally, he advocates exercising in the morning – especially outdoors – as this exposes people to bright light, which helps to synchronise our biological clocks with the time of day. Our bodies work best when the clocks in all our cells and tissues are aligned with one another, and with the time of day.

And even if there isn't a "best" time of day to work out, there may be a time to avoid exercise. Recent research by Meng and his colleagues has suggested that a key mechanism for keeping the biological clocks in our bones and joints synchronised with those in other tissues is exercise, and that if mice are encouraged to exercise when they would usually be sleeping, this causes their skeletal clocks to desynchronise from their brain clocks – a phenomenon Meng has named "skeletal jet lag".

Though the implications for injury and physical performance in humans are unclear, further experiments in mice suggest that consistently exercising during their equivalent of night-time leads to the activation of genes that are associated with osteoarthritis. "We suspect that if you did this over a long period of time, it could be really detrimental," says Meng.

Linda Geddes

HOW MUCH EXERCISE DO CHILDREN NEED?

I WASN'T a sporty child. Neither of my parents did any exercise, and if they thought I was keeping fit at school, they were wrong. In hindsight, this was a big mistake, as it is becoming increasingly clear that physical activity is hugely important for a child's cognitive and physical development, setting them on a healthier trajectory for the years to come.

So how can I do better for my own children? They are aged 5 and 7, and the UK's physical health guidelines state that those aged 5 to 18 should be racking up 60 minutes of moderate to vigorous activity on average per day, which means the kinds of things that leave them slightly hot and sweaty (think playground games or a brisk walk). The US guidelines are similar. An hour a day sounds like a lot, but remember that children tend to exercise vigorously in fits and starts, says Russ Jago at the University of Bristol, UK. Add up the moments that they spend charging about the playground or at sporty after-school clubs and it begins to feel possible. Helpfully, the guidelines stress an average of 60 minutes per day – some days might be more active, others less so, and that is alright.

Still, I couldn't really tell you what my children get up to at school, so I am in the dark about whether they meet the guidelines. I am not the only one. "Measuring physical activity is difficult in general, measuring physical activity in children is probably even more so," says Simon Cooper at Nottingham Trent University, UK. Many studies are based on self-reports, which are unreliable. And even when researchers use devices such as accelerometers, these aren't a magic bullet, as we don't know if children are wearing them consistently.

Despite this, there seems to be a consensus that most young people don't get enough exercise. In the US, 21 per cent of those aged 6 to 17 meet the guidelines. In the UK, around 60 per cent of 6-year-olds do an hour a day, but that drops steadily – by 2.5 minutes per day as they get older, says Jago. By the time children in the UK go to senior school, activity levels fall off a cliff. Jago's research has found that only about 40 per cent of 10 and 11-year-olds meet the guidelines. "It's noticeable how much fewer opportunities there are when you move to secondary school if you're not on an elite team," he says. This is especially pronounced for girls.

Beyond the amount of time spent being active, many people ignore another key part of the guidelines, says Jago – that school-age children should do a variety of different types and intensities of activity across the week to develop bone strength, movement skills and muscular fitness. "They need to do some throwing, some catching, some hopping, some skipping, some moving around to develop muscle strength and the kind of movement skills they're going to need for later life," he says.

All this matters because the list of benefits of exercise for young people is well established – and growing. Some of the long-term health gains concern risk factors for conditions such as type 2 diabetes and cardiovascular disease. "We know that those risk factors track into adulthood, so if young people are active... they are more likely to become healthy adults," says Cooper. Bone health is another biggie, for which

"Depending on what time of day you exercise, your muscle and fat cells will respond differently"

CHRIS STEELE-PERKINS/MAGNUM PHOTOS

> *"There is this perception that boys are allowed to be more active than girls"*

children should do weight-loading activity, for instance jumping on a trampoline or using a climbing frame.

When it comes to the brain, even short bursts of exercise can improve mental functioning in young people. A number of studies have found that a single session of aerobic exercise increases executive function, the higher-level thinking that is key to complex decision-making, memory and the ability to focus on key pieces of information. "In children, that's what's going to be important in school," says Cooper. There are longer-term effects on their brain function, too, with overall fitness being tied to better cognition.

Crucially, if children form a positive relationship with exercise, they are far more likely to keep it up as they get older.

But this sort of conditioning doesn't start at school age. Even babies have guidelines for physical activity, with the UK recommending that 1 to 4-year-olds do 180 minutes per day. This includes things like toddling about, splashing in puddles and playing games. By the time they are 3, they should be incorporating 60 minutes of moderate or vigorous activity as part of that overall active time.

This might sound daunting, but Kathryn Hesketh at the University of Cambridge suggests thinking about it in terms of providing more opportunities for children to simply move. Take them out of the buggy and let them walk home, for instance, even if it feels excruciatingly slow. Find ways to play more games too. There is a sweet spot where play and activity overlap, says Hesketh. "That little bit in the middle is active play," she says, and that is where you see the health benefits of exercise, but also additional mental health benefits from playing.

If, like me, you are worried that your children aren't doing enough, remember it is never too late to start doing more, but start small and find things they really enjoy. "The best physical activity is whatever physical activity they will actually do," says Cooper. The aim is that it feels natural and becomes a habit.

Small changes in the way we talk to our children can also help. We often tell them to stop running, sit down, says Hesketh. This can stifle their tendency for activity. In fact, research shows that well-behaved children tend to be less active. This is particularly pertinent when we think about ingrained expectations for the way girls and boys behave. "There's this perception that boys are allowed to be more active than girls. Even from the tiniest age group, 3 months up, physical activity metrics are higher [for boys]," Hesketh says. "I think it's really important that we allow everyone to be active."

And for younger children, try to encourage risky and adventurous play. "Society is becoming much more risk-averse, and some of the work that we're doing shows that safety is a huge barrier to physical activity," says Hesketh. "However, research shows that children who have more adventurous play have better mental health outcomes."

"If you are a parent, the key message is to figure out what they like, which probably means trying multiple things," says Jago. "The other key message is just do a bit more than you're doing now." ▮

Catherine de Lange

The back pages

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Dear David

Cutting the ties

Are there times when being estranged from our nearest and dearest may be the right answer for us? **David Robson** explores

David Robson is an award-winning science writer and author of *The Laws of Connection: 13 social strategies that will transform your life*

Resources

Stand Alone is a UK charity that offers guides for parents and children facing estrangement: standalone.org.uk/guides/

If you are struggling with mental health issues connected with estrangement, please contact your physician, who will be able to refer you to suitable services.

Dear David, an evidence-based advice column, appears monthly. Drop David a line with your social dilemmas at davidrobson.me/contact

Next week

Stargazing at home

DISAGREEMENT is an inevitable event in every relationship, and one of life's most valuable lessons is how to heal those hurt feelings. However, since I started this column, I have received many emails asking about estrangement from parents or siblings. When is it right to cut ties with someone close to us? And what are the consequences for our well-being?

I talk from personal experience when I say that this is one of the hardest decisions we ever have to make. There can be no hard and fast rules, but sociological and scientific research can help to put our own dilemmas in perspective.

Let's first consider the sheer prevalence of the phenomenon. Kyungmin Kim at the University of Massachusetts Boston and her colleagues questioned 633 adults aged 40 to 60 in the US about their contact with their parents and children – a total of 2252 bonds.

Around 38 per cent of the relationships involved little or no engagement. Around 35 per cent involved some kind of conflict or ambivalence, leaving just 28 per cent who were actively engaged and "harmonious". Happy families, it seems, are relatively hard to find, at least in this sample of people in the US.

Crucially, the team also assessed the well-being of the participants. The clearest pattern to emerge concerned those with the active and conflicted relationships, who were considerably more likely to show symptoms of depression and worse life satisfaction. Any other links to well-being failed to reach statistical significance.

ALENA KRAVCHENKO/ALAMY

I think these findings are helpful for two reasons. First, we often feel embarrassment or shame at our dysfunctional families, but these statistics should reassure us that we are by no means unusual or strange in struggling to maintain a bond to our blood relatives.

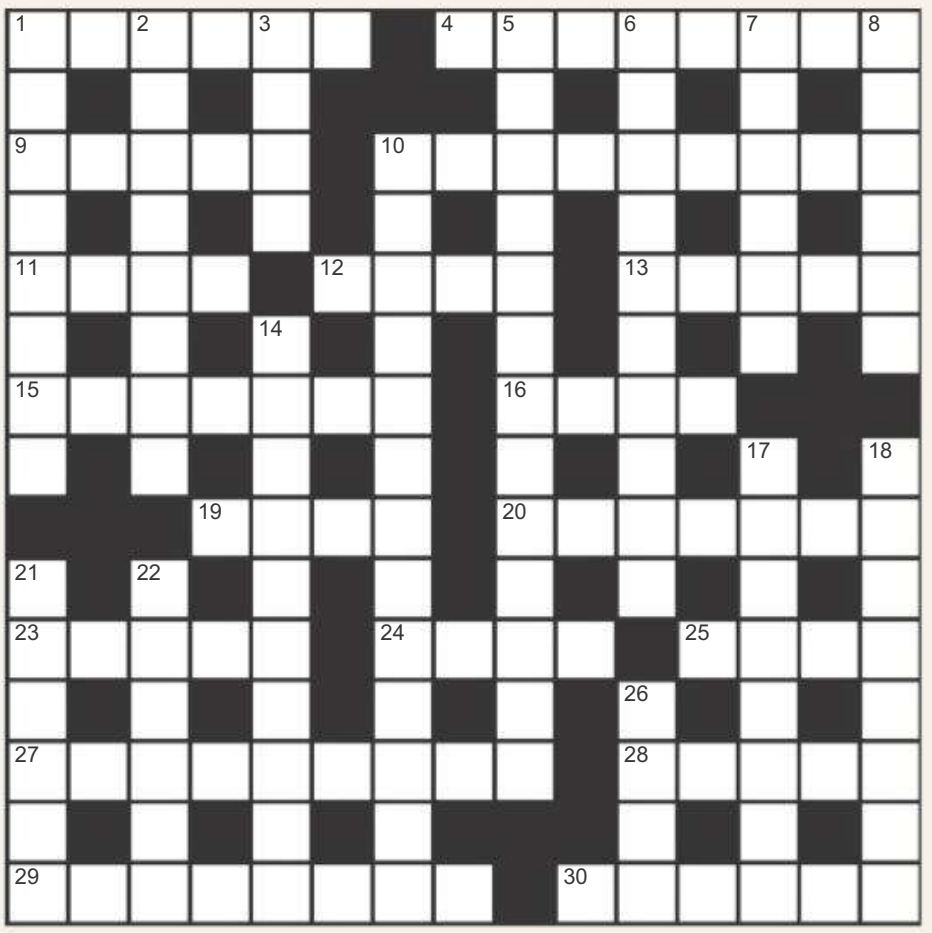
Secondly, while estrangement comes with a terrible sense of loss not unlike grief, the data suggests that distancing ourselves from a relation may be better for long-term well-being than persevering with someone who fails to treat us with respect or care. Alongside the loss can be a newfound liberty and possibility of healing.

When coming to these difficult decisions, we might consider what we think about how relationships evolve. Some people view others' personalities as immutable. With such beliefs, any error may be seen as a fatal flaw in their character. This can make it far harder to forgive a perceived transgression. Others see more potential for personal growth, which can promote greater forgiveness. That is often good, unless it means clinging on to toxic relationships that show no signs of changing.

Neither extreme is ideal. While I am a firm believer in third, fourth or even tenth chances, we must be prepared to recognise the limits of our love, and establish a suitable distance from our loved one until they have shown their commitment to change. ▮

These articles are posted each week at newscientist.com/maker

Quick crossword #163 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Structural acid found in plant cells (6)
4 Kerosene (8)
9 Ready to breed (2,3)
10 Grip marks on a wheel covering (4,5)
11 Porcini (4)
12 Fe (4)
13 See 7 Down
15 Omnivorous mammal of North America (7)
16 Division of the brain, for example (4)
19 Fast-swimming shark (4)
20 Plant, *Elaeis guineensis*, widely cultivated (3,4)
23 Deductive mathematical argument (5)
24 Social insects (4)
25 Sphere (4)
27 Printing process (3,6)
28 Coral organism, say (5)
29 Membrane transport protein (8)
30 Star in the constellation Gemini (6)

DOWN

1 Henri ___, French mathematician and physicist (8)
2 Outer shell (8)
3 [illegible] (4)
5 Hormone production site, in humans (7,6)
6 Car (10)
7/13 Mathematics award (6,5)
8 Small mineral cluster (6)
10 Theropod dinosaur genus (13)
14 Eruption of radiation from the sun (5,5)
17 Of lines, not intersecting (8)
18 Disease eradicated in 1980 (8)
21 Accelerated (4,2)
22 PhD (6)
26 No more than (2,2)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #262
set by Bethan Ackerley

1 What is the atomic number of iron?
2 Ren Zhengfei is the founder of which tech firm?
3 Loxoscelism is a condition caused by the bites of which spiders?
4 Which stage of embryonic development comes first: the morula or the blastocyst?
5 Which proteins are the primary emulsifiers in milk?

Answers on page 47

BrainTwister
set by Peter Rowlett
#30 Digital targets

You are playing a game in which you have to arrange 10 random single-digit numbers (which can include 0) to form five two-digit numbers, aiming for five targets: 10, 20, 30, 40 and 50.

If you match a target exactly, you score that number. If you get within 5 of a target, you score half the value of the target. Otherwise you score zero for that target.

For example, if you are given the numbers 1, 2, 2, 3, 3, 5, 5, 7, 8 and 9, you can arrange them to get a total score of 60, as shown in the table below (although this isn't the optimal score with these numbers).

Target	Digits		Value	Score
10	1	7	17	0
20	2	8	28	0
30	3	5	35	15
40	3	9	39	20
50	5	2	52	25
			Total	60

Which 10 single-digit numbers would let you make the maximum possible score?

What's the highest score you can make if you are given the numbers 0, 1, 1, 2, 3, 4, 5, 9, 9 and 9?

If you were given one of each digit 0–9, what is the highest score you could get?

Solution next week

Adding up

Did abstract mathematics, such as Pythagoras's theorem, exist before the big bang?

Simon McLeish
Lechlade, Gloucestershire, UK
The notion of the existence of mathematical ideas is a complex one.

One way to look at it is that mathematics is about the use of logical thought to derive information, often information about other mathematical ideas. The use of objective logic should mean that mathematical ideas are eternal: they have always been, and always will be.

Pythagoras's theorem holds true now, was true before the big bang and will be true when there are no human beings to understand it. Secondly, it could be argued that without an intelligent mind able to comprehend it (and prove it), the theorem can't be said to exist. In other words, until someone came up with the concepts involved (lines, angles and the relationship between them) and put them together, the theorem effectively didn't exist. The actual proof of Pythagoras's theorem probably

"It could be argued that without an intelligent mind to comprehend it and prove it, Pythagoras's theorem can't be said to exist"

originated before Pythagoras, and Pythagorean triples – three numbers that could be the sides of a right-angled triangle – are an older concept (but still more recent than the big bang).

A third possible opinion is that pure mathematics doesn't really exist at all – never has and never will. While mathematicians tend to use visualisations to view mathematical "objects" such as sets and functions, mathematics is about abstracted objects that ignore reality. For instance, a line without width couldn't exist in the real world, but that is a property of a line in geometry, and the numbers that are used to measure the sides of a right-angled triangle have a mathematical precision far finer than could be obtained from a real-life triangle.

Perfection is the soul of mathematical thinking, but it never exists in the real world.

Nick Canning
Coleraine, County Londonderry, UK
The big bang is a singularity in space-time, so the notion of "before the big bang" is meaningless. Are you asking "Is mathematics a pre-existing reality or a free creation of the mathematician?" Both positions have been asserted.

Plato thought mathematical truth exists in some immaterial, nontemporal, non-physical mental realm of universal forms and that the mathematician doesn't so much discover it as remember it from when their own pre-existing immortal soul (mind) was in contact with these forms.

Rejecting this view of mind, I think mathematics is the logical working-out of necessary conclusions from sets of mutually consistent axioms, freely chosen by the mathematician. The fact that it is useful relies on the axioms you choose being a good representation of relations found in nature, which you are interested in describing.

Pythagoras's theorem is then a necessary truth of Euclidean geometry and applies to "flat space", but it isn't a truth of curved space such as the geometry of the surface of a sphere. If the curvature of physical space is sufficiently small, then Pythagoras's Theorem will be a useful approximation to the truth of measurements in that space, whatever the time of the measurement.

Roger Leitch
Bath, UK
There are those mathematicians who believe mathematics is invented, for whom the answer is no because there was nobody to write it down, and those who believe it is discovered, for whom the answer is yes.

The latter are called Platonists, after Plato and his forms. There is justification in their belief, because we can consider mathematical problems that cannot be solved, in that we cannot write a solution down, but we can prove a solution exists. Not only that, we can find properties of the solution – we may be able to answer the question, "Is the solution bounded?" for example.

This approach can be useful. When looking at a problem in engineering, for example, it may be impossible to calculate all the stresses at every point in the structure of a bridge, but we can obtain an upper bound on these stresses, and the engineers can ensure everything is strong enough to withstand these stresses.

The majority of mathematicians are platonists, if for no other reason that it makes life easier.

Hillary Shaw
Newport, Shropshire, UK
Arguably yes, irrespective of what was before the big bang, if there was a "before". The integers are independent of anything else. We start with zero, the basis of all maths, the null set A, because zero anything is identical to zero anything else. Then we have set B,

ANDREW SPARKES/ALAMY

All creatures great and small – but is there an upper limit for how big an animal can be?

This week's new questions

Size matters **What is the largest size an animal can be?**
Simon Rawle*, Crondall, Hampshire, UK*

Seeing is believing **How do I know if what I see is actually there?** ***Oliver Broughton (age 10)****, Madrid, Spain*

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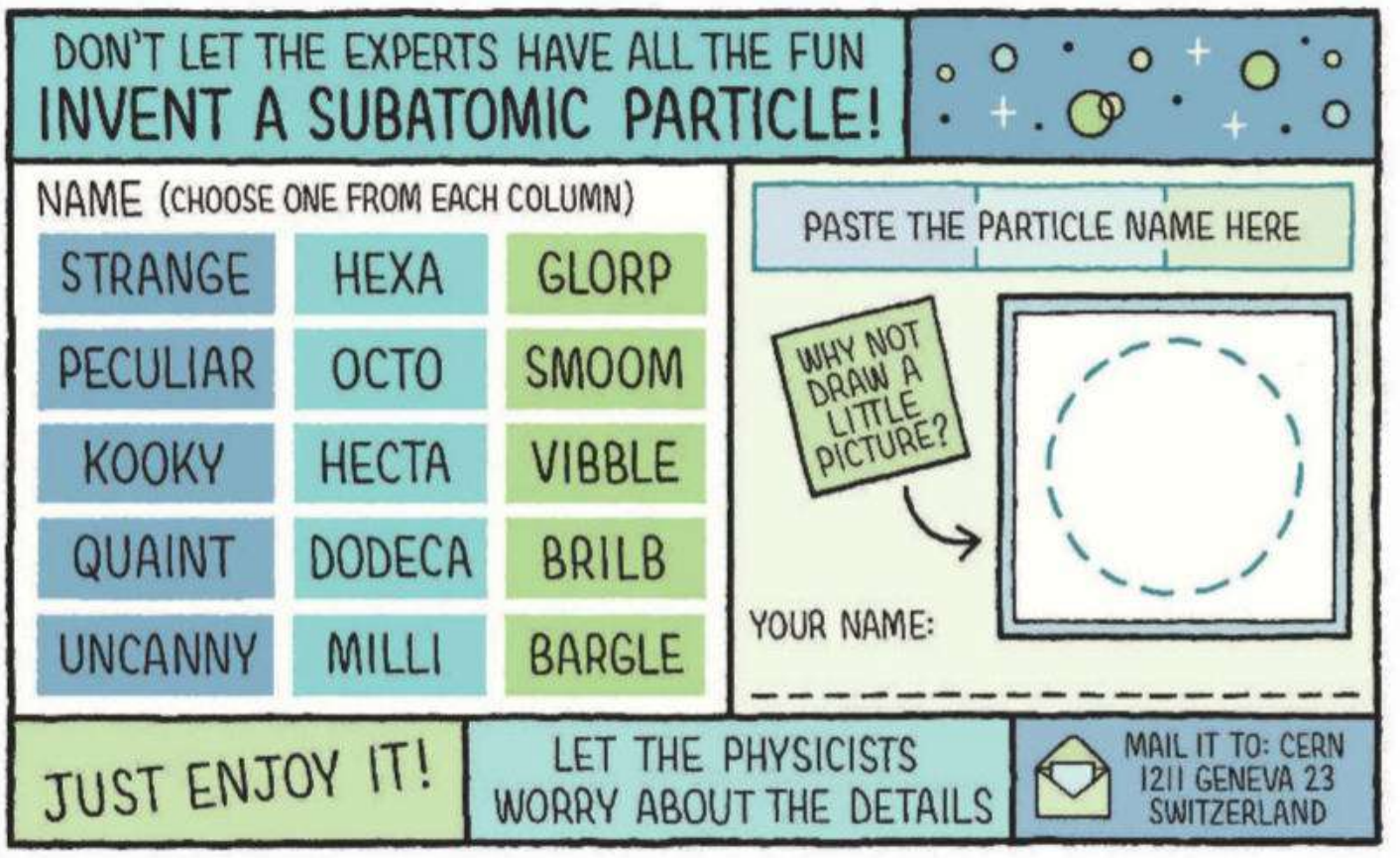


containing just the null set A, so we have a one-member set, then set C containing just sets B and A, with two members and so on. No need for a universe or a Greek philosopher or anything else. Then $3^2 + 4^2 = 5^2$ is "always" true, and 8,329,661 is "always" the 560,472nd prime, and so on.

Eric Kvaalen
Les Essarts-le-Roi, France
I believe that abstract mathematics exists outside of space-time, but the question presupposes that there was such a thing as "before the big bang". That's not at all certain!

Child's play

At what age would a human child be capable of surviving in the wild? (continued)

Elaine Coates
Stockport, Greater Manchester, UK
That very much depends on their familiarity with the land.

Last year, a group of Colombian children aged 13, 9, 4 and 1

"Last year, a group of Colombian children aged 13, 8, 4 and 1 survived in the jungle for 40 days after a plane crash"

survived in the jungle for 40 days after a plane crash. The older children not only managed their own survival but also kept their siblings alive.

The children were from an Indigenous group and had learned survival skills from their grandmother.

Jonathan Wallace
Newcastle upon Tyne, UK
The answer to this question surely depends very strongly on the community from which the child in question comes.

Children from forest-dwelling societies in, say, Amazonia or the Congo rainforests will have absorbed many lessons from simply observing their parents going about the business of daily life in much the same way as a small child from London or New York will pick up on many of the normal "survival" behaviours in a modern city. Consequently, the forest child will inevitably be capable of surviving "in the wild" at a much earlier age than the city child.

Without prior training, many Western adults would struggle to survive in the wild, particularly if they weren't provided with key survival tools such as knives, flint and steel and so on.

S Pollok
Watten, Caithness, UK
Probably when they are old enough to own their own smartphone.

Finding themselves in the wild with no signal, they could try climbing the nearest hill to get a signal.

Failing that, they could then fire up their offline survival app that they downloaded. If they also had a penknife, solar charger and cigarette lighter, they would stand a pretty good chance of surviving for longer than a few days. ▮

Answers

Quick quiz #262 *Answers*

1 26
2 Huawei
3 Recluse spiders (*Loxosceles*)
4 The morula
5 Caseins

Cryptic crossword #140 *Answers*

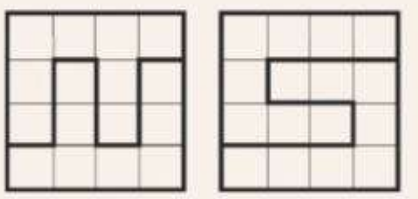
ACROSS 1 Faint, **4** Gushers, **8** Capsids, **9** Wheel, **10** Lecturer, **11** Weld, **13** Yes-man, **15** Midrib, **18** Glam, **19** Paraffin, **22** Ample, **23** Caldera, **24** Herriot, **25** Winch

DOWN 1 Faculty, **2** IUPAC, **3** Tribunal, **4** Gasped, **5** Sows, **6** Eyewear, **7** Solid, **12** Disallow, **14** Snapper, **16** Bone ash, **17** Mascot, **18** Graph, **20** Freon, **21** SETI

#29 Four by four *Solution*

With an 8-centimetre length cut, the following divides the grid into two identical halves.

For a 10-cm cut, there are two ways of doing this.



Cosplay coral-ation

Getting anyone, anyone at all, to notice what you have discovered is a problem for almost every scientist. (It's a problem also for almost anyone anywhere who discovers almost anything.)

Mark Patterson at Northeastern University in Massachusetts and his colleagues tried being theatrical to raise awareness about marine microplastics. They found success ("attentive engagement") by doing cosplay at a Comic-Con convention in San Diego. Patterson wore a giant coral costume and wielded a swordlike "microplastics sampling device", while another team member was dressed as Greek sea goddess Amphitrite, "with bracelets and hair made with plastic debris".

"We found that the novelty factor of our costumes and accessories, not part of the traditional cosplay pantheon of characters, was a captivating way to engage convention attendees," they say. "Engagement lasted 1–8 minutes in length, with 1–9 attendees at a time."

Readers of *Current: The Journal of Marine Education* can see stimulating photographs of the adventure, then, properly roused, go read up about microplastics.

Twisteddoodles *for New Scientist*

SO SCISSORS CUTS PAPER
AND ROCK BREAKS SCISSORS
BUT PAPER WINS AGAINST ROCK
AND THAT'S YOUR BEST PLAN TO STOP THE METEOR?!
@twisteddoodles

Got a story for Feedback?

Send it to feedback@newscientist.com
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Consideration of items sent in the post will be delayed

What's on your mind?

Feedback wonders whether people who professionally think about thinking really think anyone really thinks those thinkers know much about it.

Those thinkers who think about thinking are called many things: cognitive scientists, brain scientists, neurologists, neuroeconomists, philosophers, neurophilosophers, psychologists, neuropsychologists, psychiatrists, neuropsychiatrists, therapists, neurotherapists, theologians, neurotheologians, intellectual historians, et al.

Never mind that they call each other many things, not always admiringly.

The professionals quibble about consciousness. In the past five years alone, nearly 2000 academic papers have publishingly explored the question "What is consciousness?"

And they ruminate about ruminating. For example, Christopher Marcin Kowalski, Donald Saklofske and Julie Aitken Schermer at the University of Western Ontario in Canada published a paper in May called "What are you ruminating about? The development and validation of a content-dependent measure of rumination". These three ruminators say they think that "existing measures of rumination assess ruminative thought without reference to the content of ruminations".

What is the content of these ruminators' own ruminations? In some of their other papers, they give us glimpses.

Schermer ruminated in 2023 on the owners of noisy automobiles, in a brief report titled "A desire for a loud car with a modified muffler is predicted by being a man and higher scores on psychopathy and sadism".

Kowalski and Saklofske ruminated in print on "Enthusiastic acts of evil".

Saklofske also ruminated, also in print, on "measuring gelotophobia, gelotophilia, and katagelasticism".

Now perhaps you too – if aided by a dictionary – will ruminate on gelotophobia, gelotophilia and katagelasticism.

Exploding insights

Questions arising from underground explosions, including those of buried, embalmed corpses, and toxic groundwater (Feedback, 20 July) continue to spur thought.

William Drennan, a law professor at Southern Illinois University, casts a cold eye at the practice of embalming. He writes in the *Dickinson Law Review* that: "Attempts to make caskets air-tight and water-tight have led to a phenomenon termed 'exploding casket syndrome.' Basically, efforts to make caskets air-tight and water-tight lead to a disturbing conclusion because heat, gas, and liquid build up inside the coffin as the body decomposes, eventually causing an explosion."

Leaving aside the intrinsic value of tradition, Drennan says "there appears to be no benefit to embalming after the public viewing".

Recognising the intrinsic value of knowledge, Wei Guo and colleagues at the Army Engineering University of PLA in China published a wide-ranging look in the journal *Underground Space* at the "theory and test of underground explosions".

They summarise "a large number of field tests and numerical simulations [that] have been conducted at home and abroad".

Though they don't specifically mention exploding, buried, embalmed corpses, the team does warn that: "Calculating the parameters of the ground shock induced by an underground explosion is a complex energy coupling problem."

Saying it all

We have two additions to Feedback's collection called The Title Tells You Everything You Need to Know.

"A man who pricked his finger and smelled putrid for 5 years" edified readers of *The Lancet* in 1996, while "Dizziness in discus throwers is related to motion sickness generated while spinning" informed subscribers to *Acta Oto-Laryngologica* in 2000.

If you find an equally prickly, smelly or dizzyingly clear example, please send it (with citation details) to: Telltale titles, c/o Feedback. ▮

Marc Abrahams

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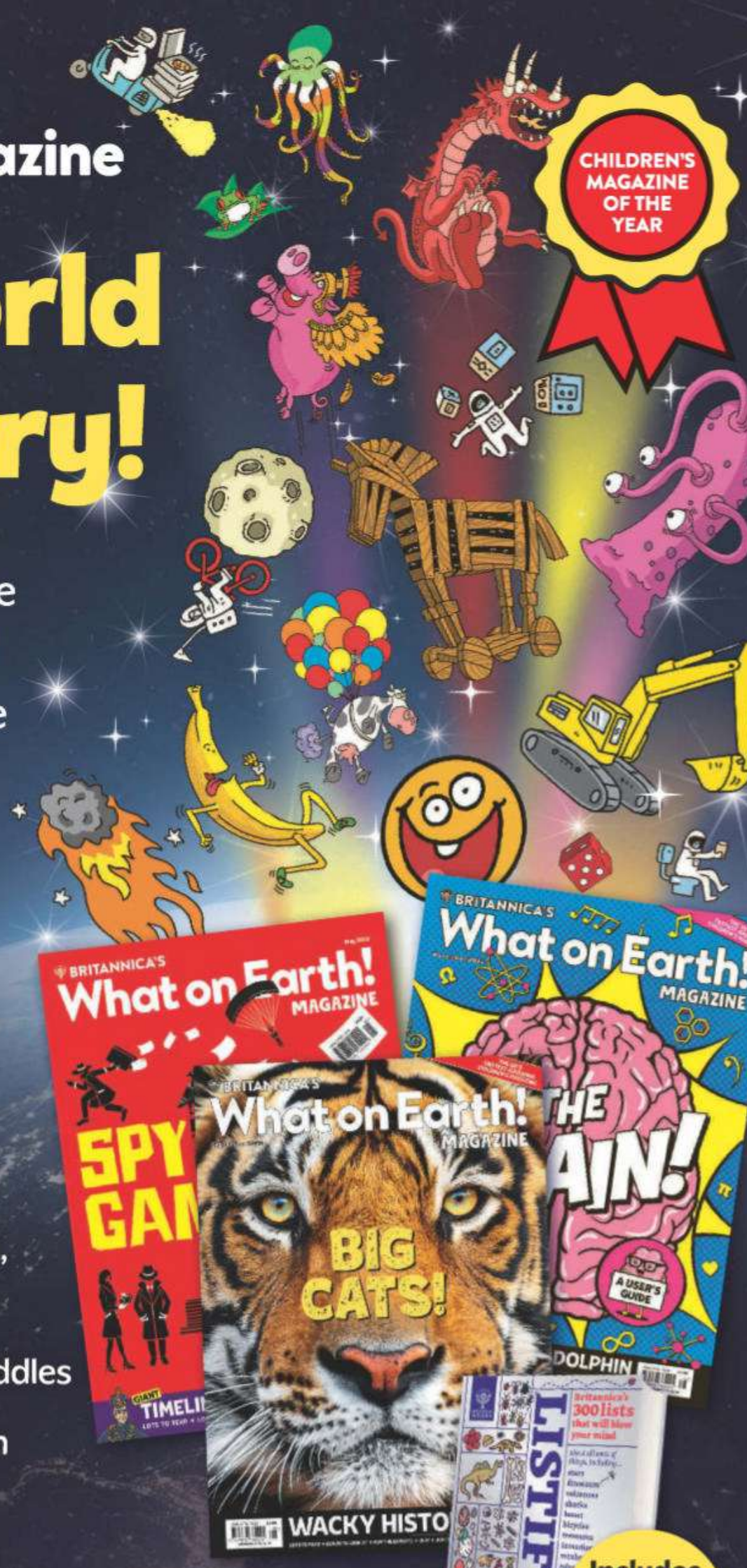

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